

FIG. 1

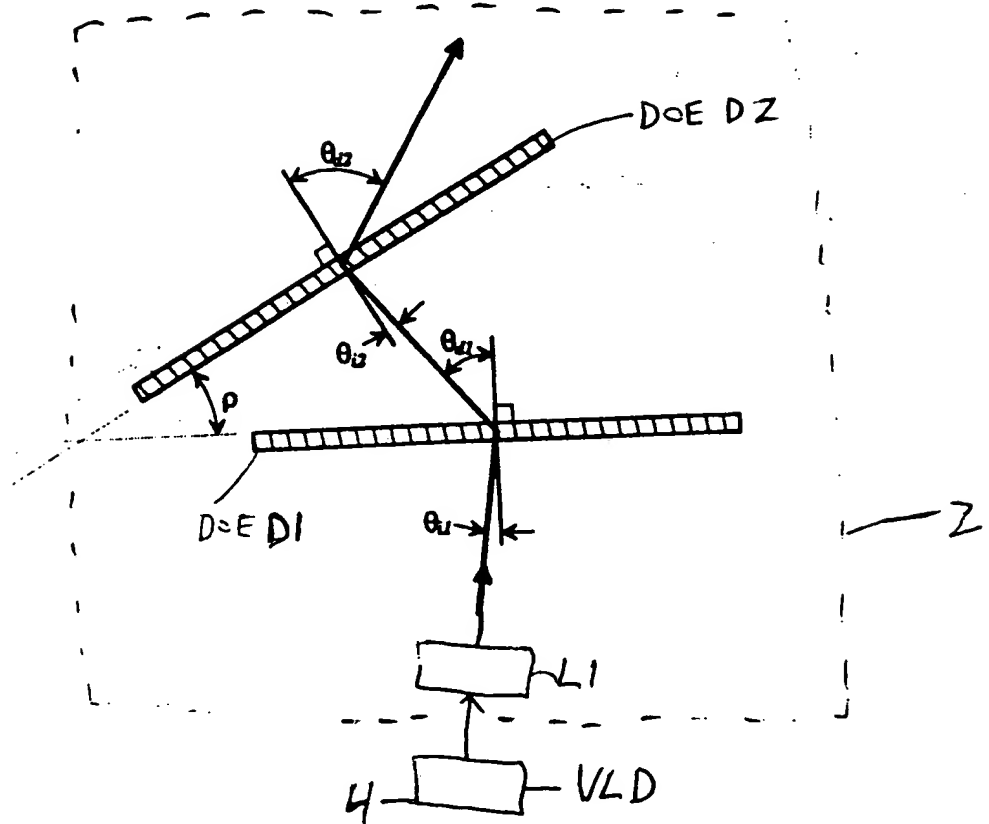


FIG. 1A

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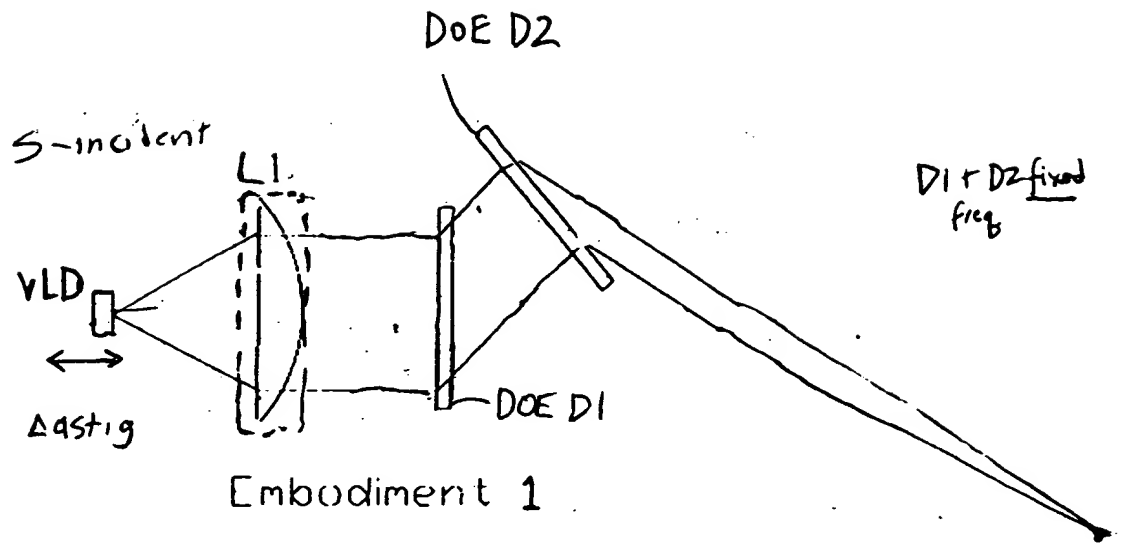
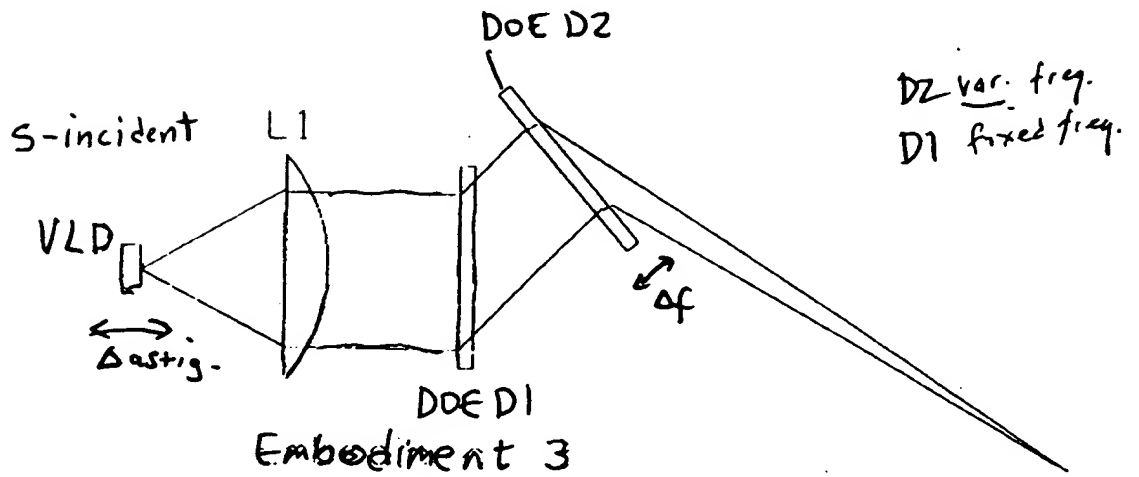
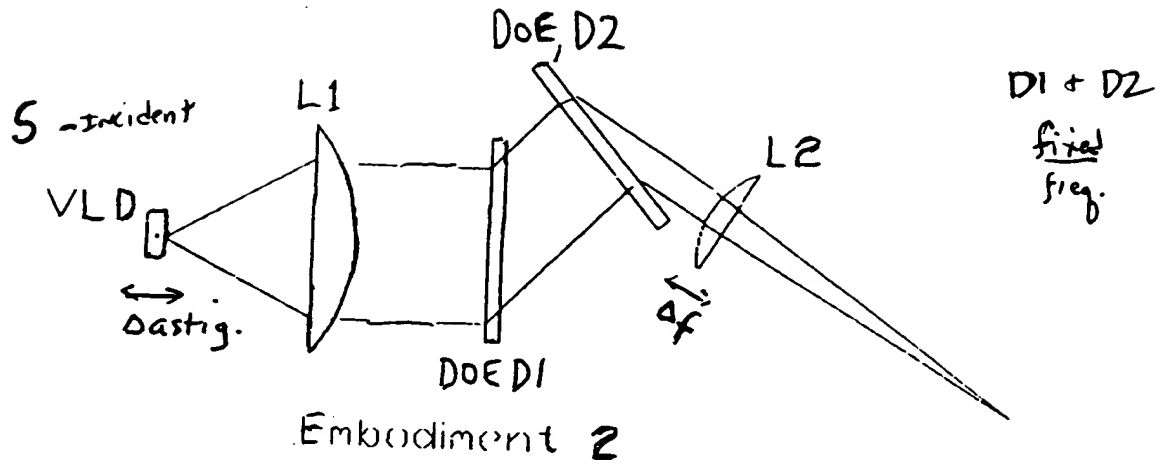


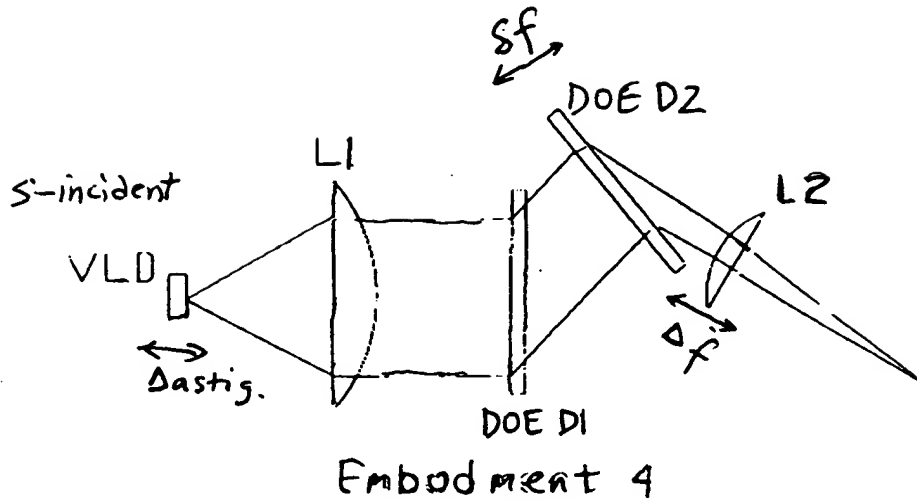
FIG 2A

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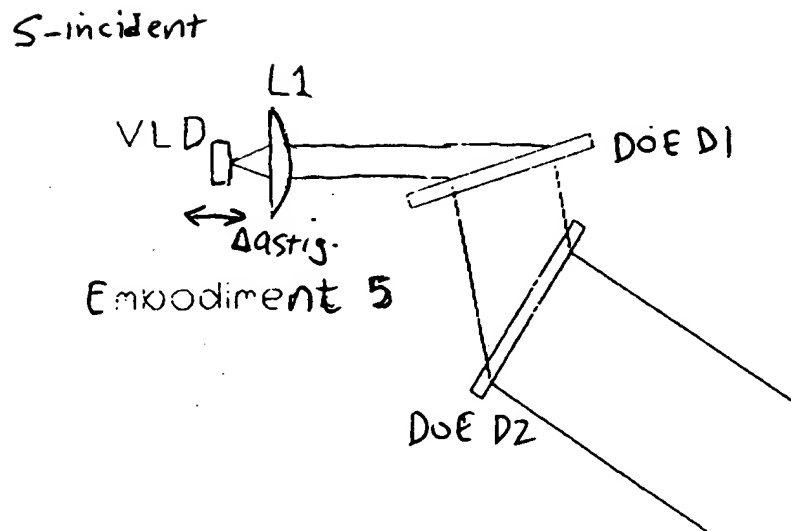
09955123-092701

4/59



D1 fixed freq.  
D2 var. freq.

FIG. 2D

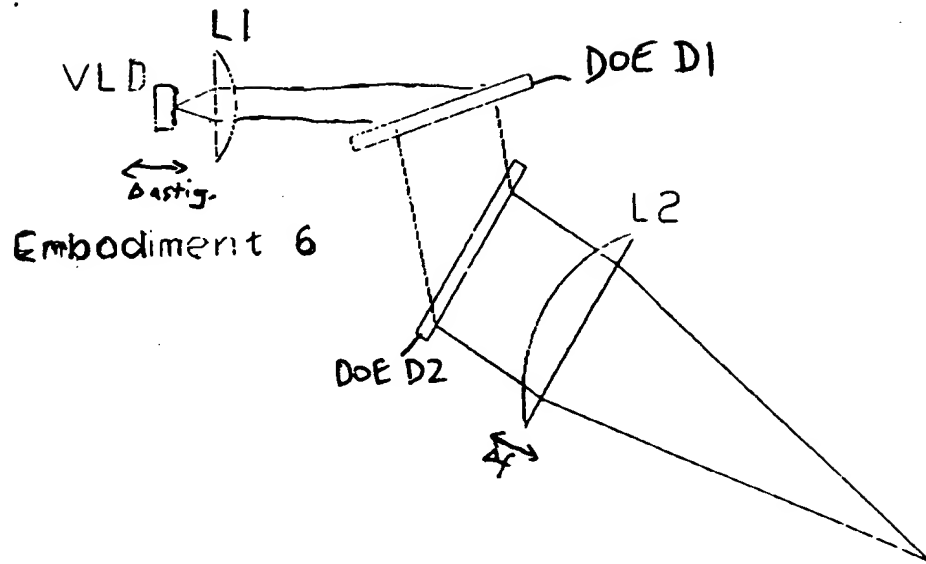


D1 + D2  
fixed freq.

FIG. 2E

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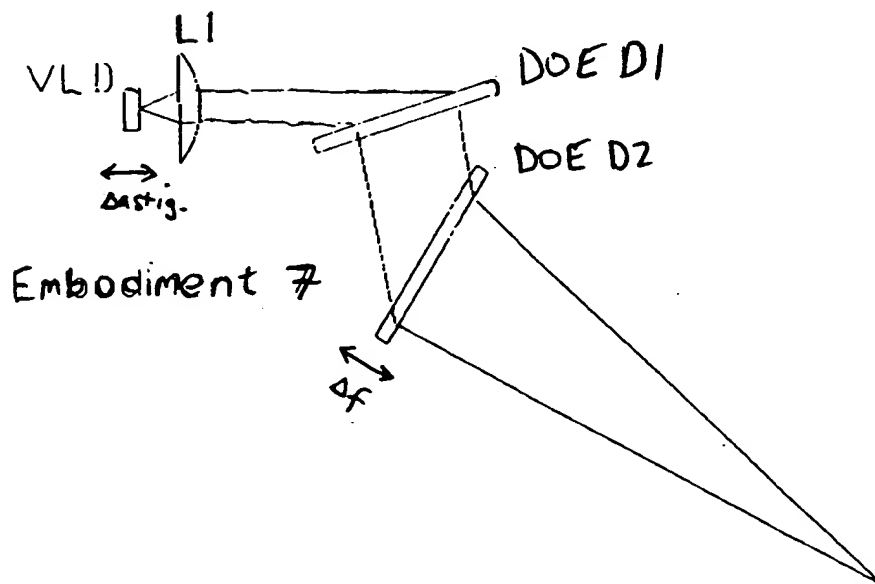
5/59



D1 + D2  
fixed  
freq.

FIG. 2f

~~Embodiment~~



D1 fixed freq.  
D2 var. freq.

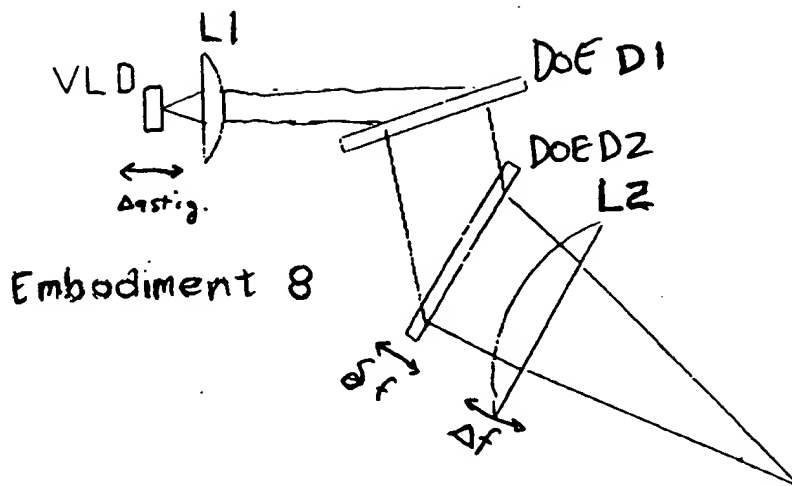
FIG. 2g

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6/59

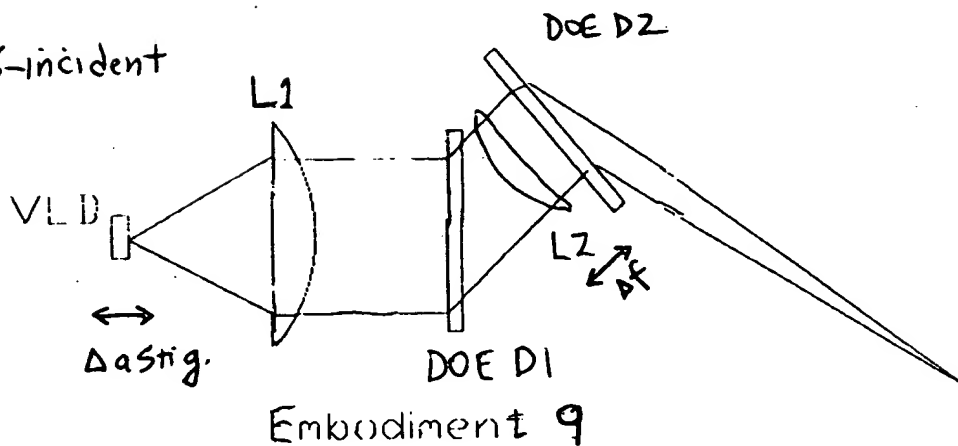
P-incident



D1 fixed freq  
D2 var. freq

FIG. 2H

S-incident



D1 + D2  
fixed  
freq.

FIG. 2I

7/59

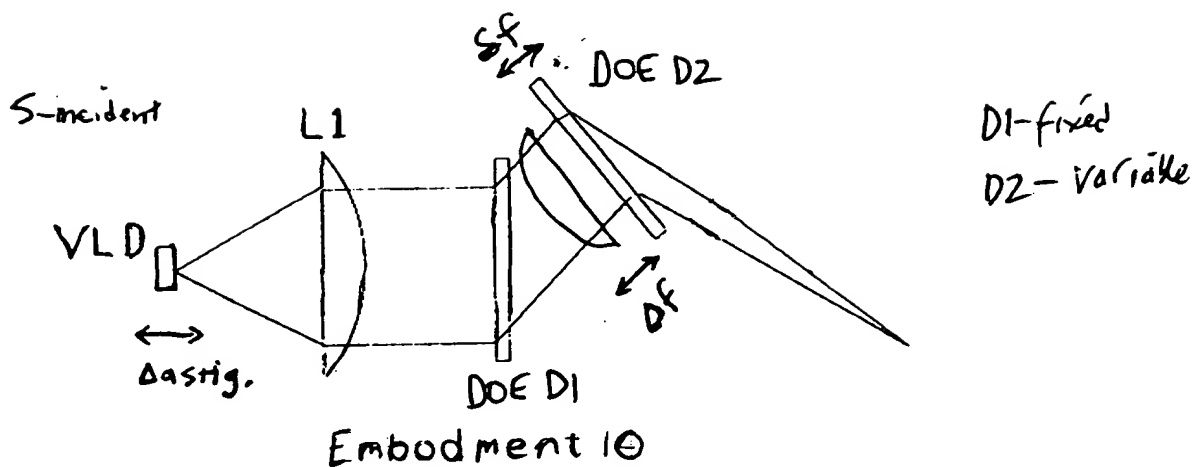


FIG. 2J

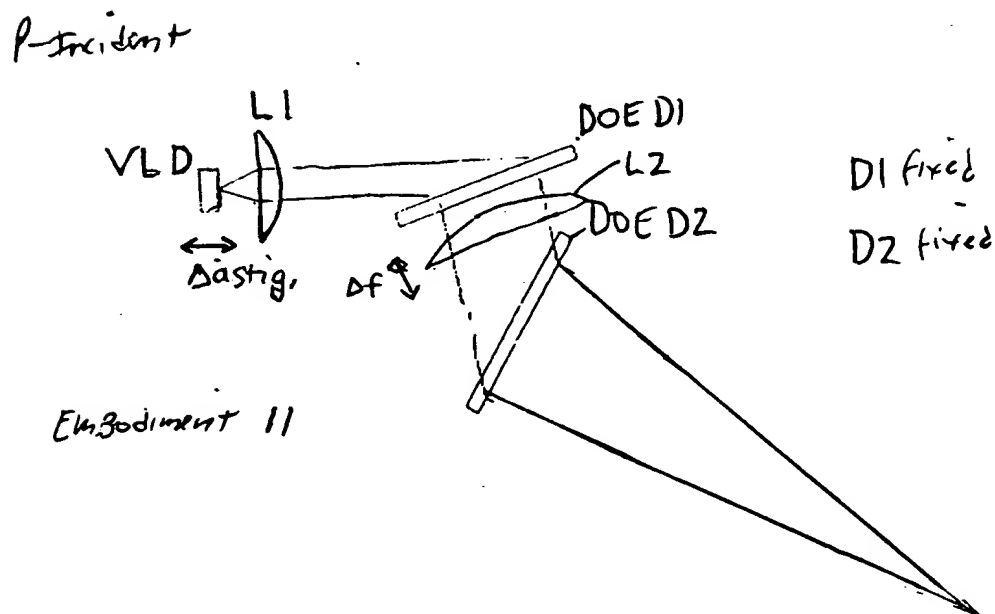


FIG. 2K

8/59

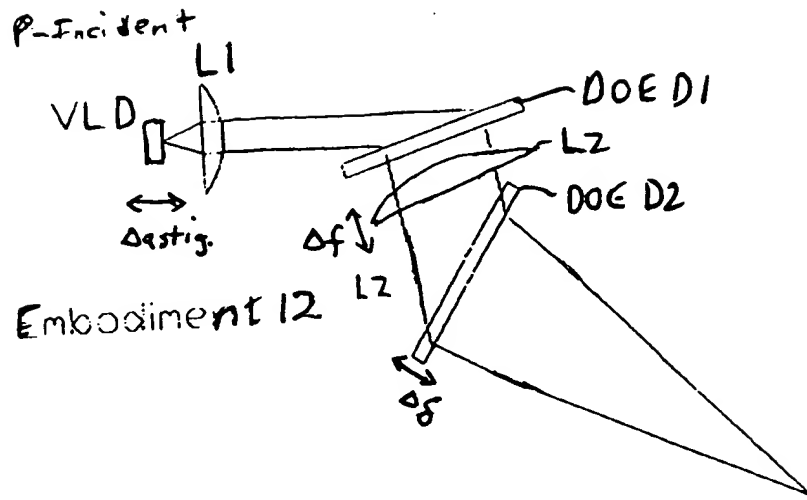


FIG. 2L

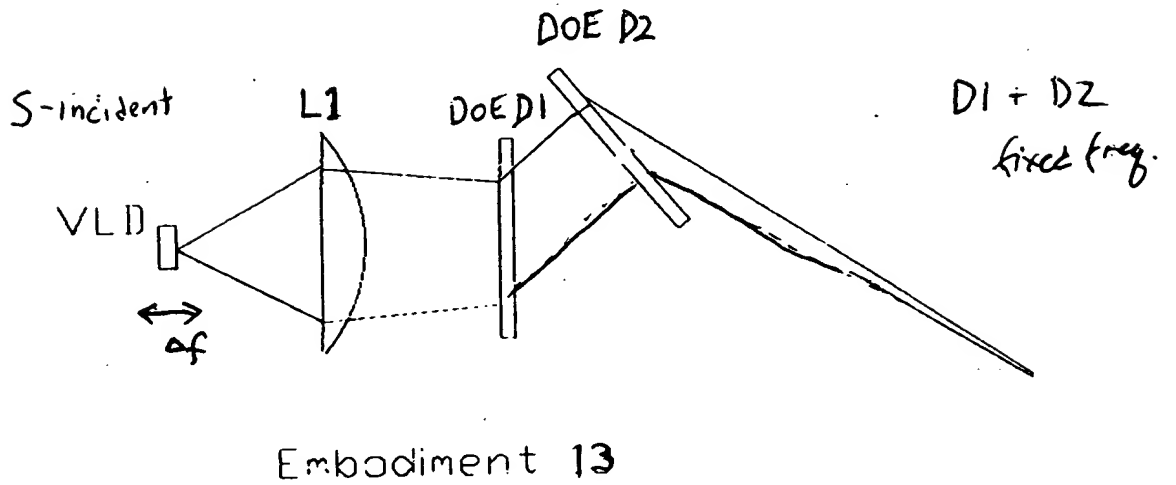
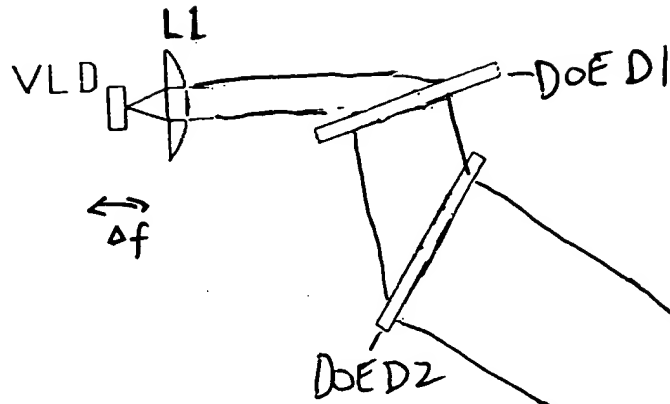


FIG. 2M

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P-incident



Embodiment 14

FIG. 2N

0995123-092701

10/59

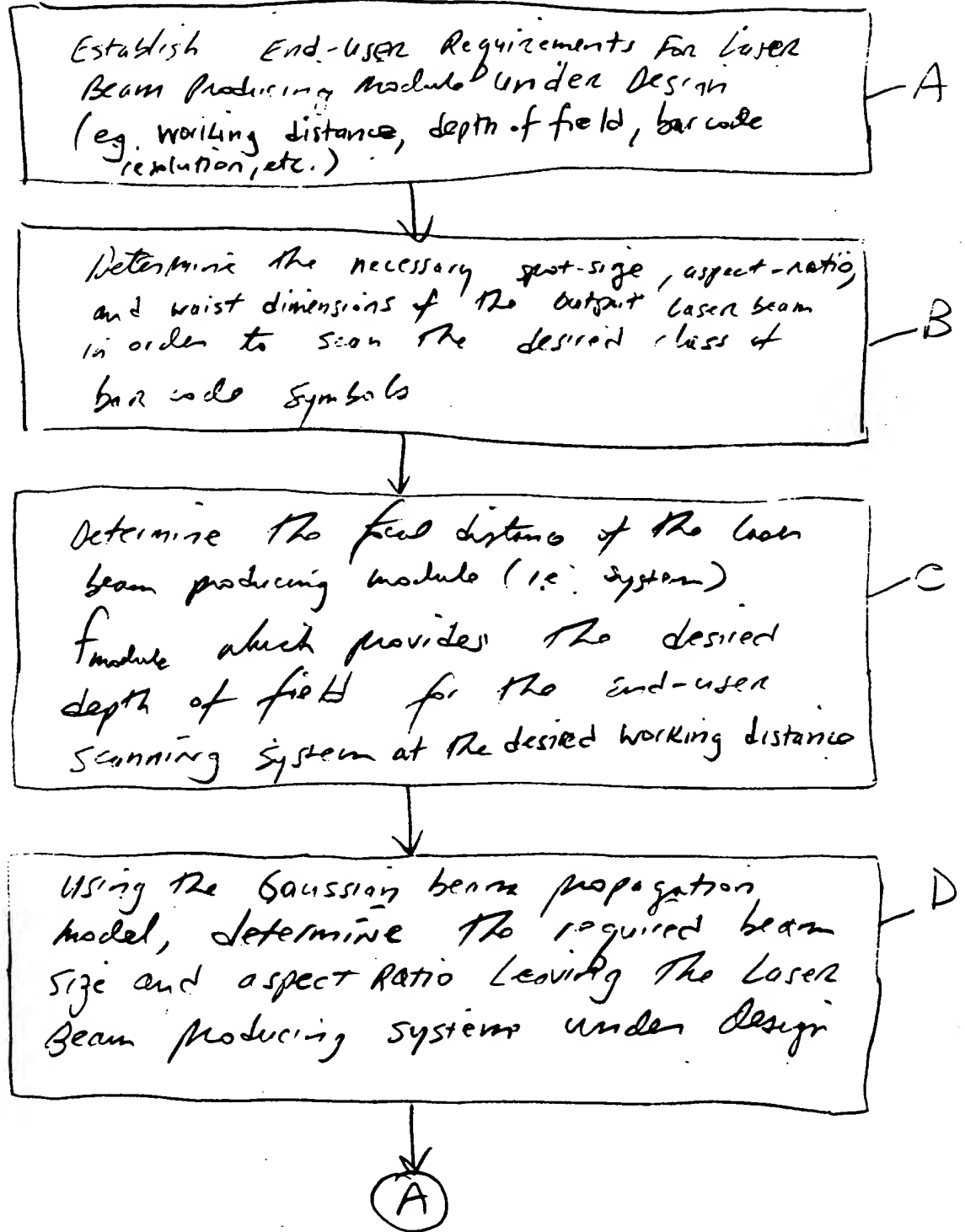


FIG. 3A1

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11/59

(A)

Choose a laser source (eg VLO) having acceptable beam characteristics and an acceptable amount of beam astigmatism

E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (ie DOE<sub>D1</sub> and DOE<sub>D2</sub>) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D.

F

use the Beam Shaping Factor determined at Block F to determine the HOE construction parameters ( $\theta_{01}, \theta_{R1}, \theta_{02}, \theta_{R2}, p$ ) specified at Reconstruction wavelength  $\lambda_R$  for DOEs D1 and D2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B

G

(B)

FIG 3A2

12/59

(B)

determine the distance from the VLD  
to first lens element L1 which  
produces an output laser beam having  
the desired beam size determined  
at Block D

H

determine the focal length of  
lens element L1 that produces  
an output laser beam having  
the desired focal length  
determined at Block C

I

FIG 3A3

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13/59

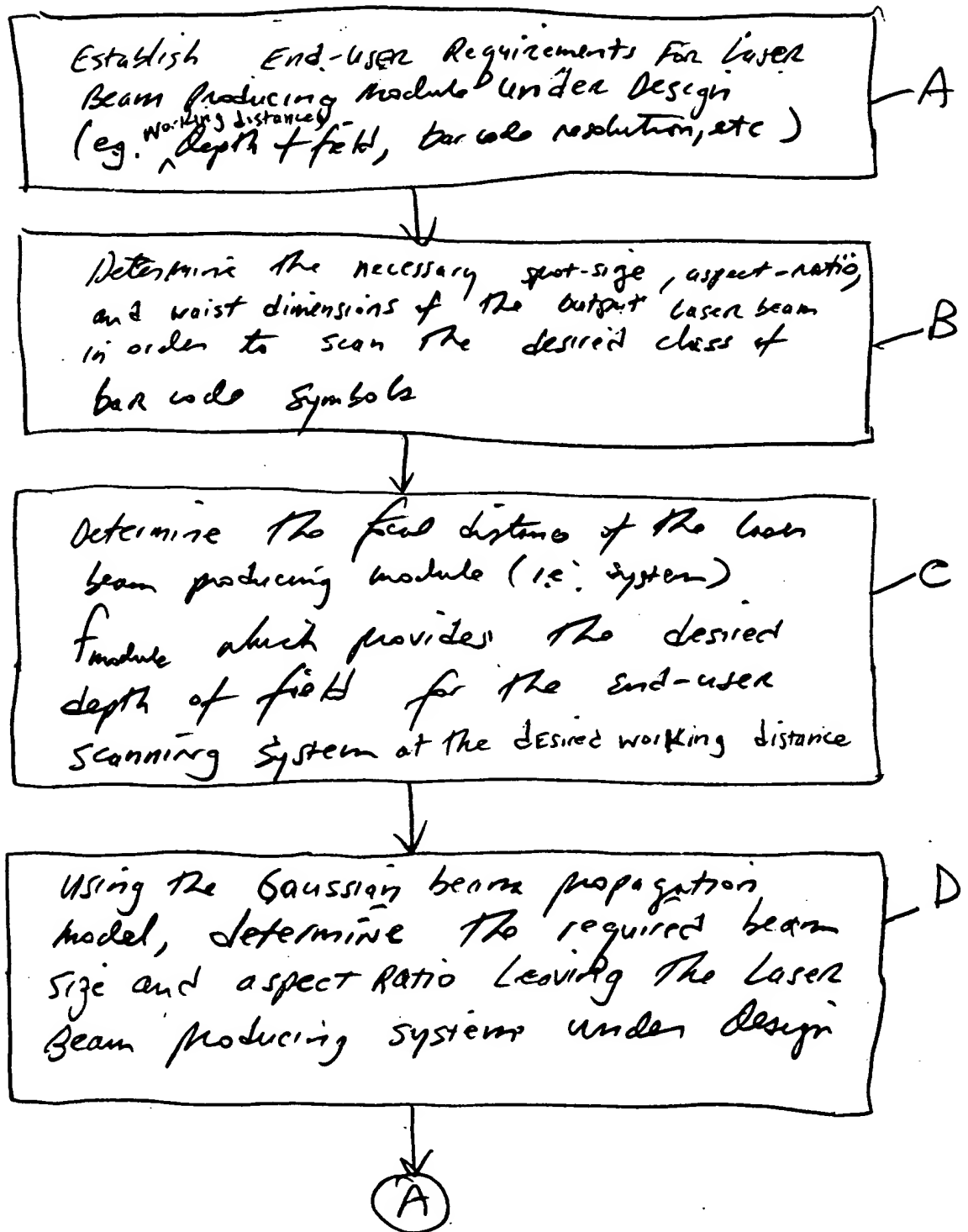


FIG. 3B1

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14/59

(A)

Choose a laser source (eg. VLO) having acceptable beam characteristics and an acceptable amount of beam astigmatism

E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (i.e. HOEs H1 and H2) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D.

F

Use the Beam Shaping Factor determined at Block F to determine the HOE construction parameters ( $\Theta_{01}, \Theta_{R1}, \Theta_{02}, \Theta_{R2}, P$ ) separated at reconstruction wavelength  $\lambda_R$  for HOEs H1 and H2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B

G

(B)

FIG. 3B2

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(B)

15/59

determine the distance from the VLD to first lens element L1 which produces an output laser beam having the desired beam size determined at Block D

Determine which optical component of the system will converge/diverge the laser beam from the VLD so that upon adjusting the separation between the VLD and lens L1, the convergence or divergence of the non-collimated laser beam entering the DOE-based subsystem cancels out the inherent astigmatism in the beam produced by inherent characteristics of the VLD.

Determine the optical parameters in the laser beam producing system under design to yield the desired focal distance in the output laser beam determined at Block C

FIG. 3B3

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16/59

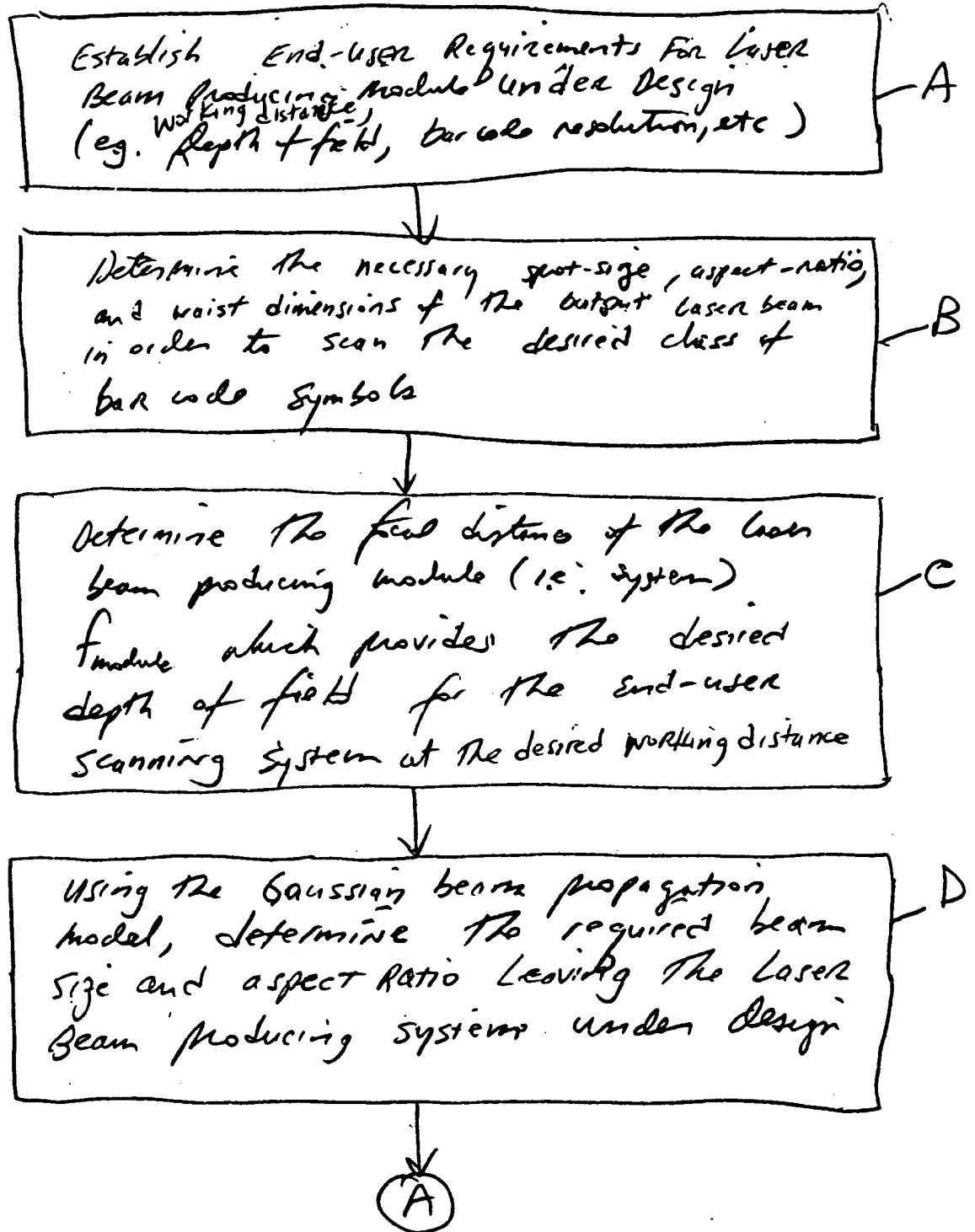


FIG. 301

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(A)

Choose a laser source (eg. VLO) having acceptable beam characteristics and an acceptable amount of beam astigmatism

E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (i.e. DOEs D1 & D2) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D.

F

Use the Beam Shaping Factor determined at Block F to determine the HOE construction parameters ( $\theta_{01}, \theta_{R1}, \theta_{02}, \theta_{R2}, p$ ) separated at reconstruction wavelength  $\lambda_r$  for DOEs D1 and D2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B

G

(B)

FIG. 3C2

(B)

10/59

determine the distance from the VLD to first lens element L1 which produces an output laser beam having the desired beam size determined at Block A

determine the focal length of lens L1 so that, when the correct amount of separation exists between the VLD and lens L1, the resulting convergence/divergence of the laser beam will eliminate astigmatism upon passing through DOE D1 only.

Assume DOE H2 is a stigmatic-type optical element and determine the focal length of lens L2 so that desired average focal length is achieved in output laser beam

determine construction of DOE D2 to produce desired focal length through lens L2

FIG 3C3

09965123-092701

19/59

ESTABLISH END-USER Requirements  
for the laser beam producing module  
under design (e.g. final aspect-ratio  
and spot size)

A

use the Gaussian beam propagation  
model to determine the required  
beam aspect-ratio leaving the laser  
beam producing system in order to  
produce the specified aspect-ratio  
at focus

B

choose an acceptable laser source (e.g. VLD)  
having an acceptable degree of beam  
divergence, astigmatism, aspect-ratio,  
wavelength and bandwidth

C

determine an appropriate value for  
the beam-shaping factors of the  
DOEs D1 and D2 which ensures that  
the aspect-ratio of the beam entering  
the laser beam modifying subsystem is  
sufficiently modified so that the output laser  
beam has the desired aspect-ratio.

D

FIG. 3D1

(A)

09965123-092701

20/59

(A)

determine the construction angles  $\theta_{i1}, \theta_{d1}, \theta_{i2}, \theta_{d2}$  (expressed at reconstruction wavelength  $\lambda_r$ ) for the two DOEs D1 and D2 which provides an optical subsystem wherein the laser beam output from the second DOE D2 thereof has (1) effectively zero net beam dispersion, and (2) the desired aspect-ratio determined at Block B

determine the convergence of the beam leaving lens L1 that will adjust or eliminate the astigmatism produced by the VLD

use the Gaussian beam propagation model to determine the required beam spot size leaving the laser beam producing system in order to produce the focused spot size determined at Block A

determine the distance from the VLD to the first lens element L1 that produces an output laser beam having the desired beam size determined at Block G

(B)

09965123-092701

21/59



determine the focal length of lens  
element L1 that produces a beam  
with the convergence determined in  
Block F

I

FIG 3D3

09965123-092701

22/59

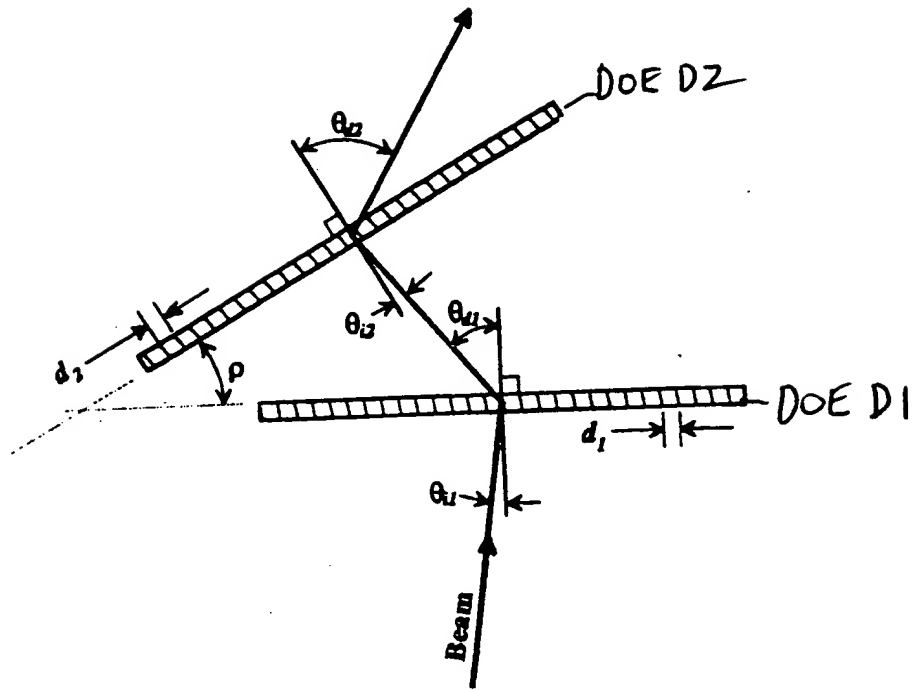


FIG. 3E

23/59

choose values for compression/expansion ratios  $m_1$  and  $m_2$  so that the beam shaping factor satisfies  $m < m_1, m_2$ , choose reconstruction (design) wavelength  $\lambda_R$ , and angle of incidence  $\theta_{i1}$ .

Solve for the angle of diffraction  $\theta_{d1}$  at DOE D1 using Equation No. 4

Solve for the fringe structure spacing  $d_1$  of DOE D1 using Equation No. (1)

Solve for the angle of incidence  $\theta_{i2}$  at DOE D2, using Equation No. (7)

Solve for the DOE tilt angle,  $\phi$ , using Equation No. (3)

A

FIG 3 F1

0995123-092701

24/59

A

Solve for the angle of diffraction  $\theta_{d2}$   
at DOE DZ using equation NO. (5). F

Solve for the fringe spacing  $d_z$   
within DOE DZ using equation NO. (2) G

FIG. 3F2

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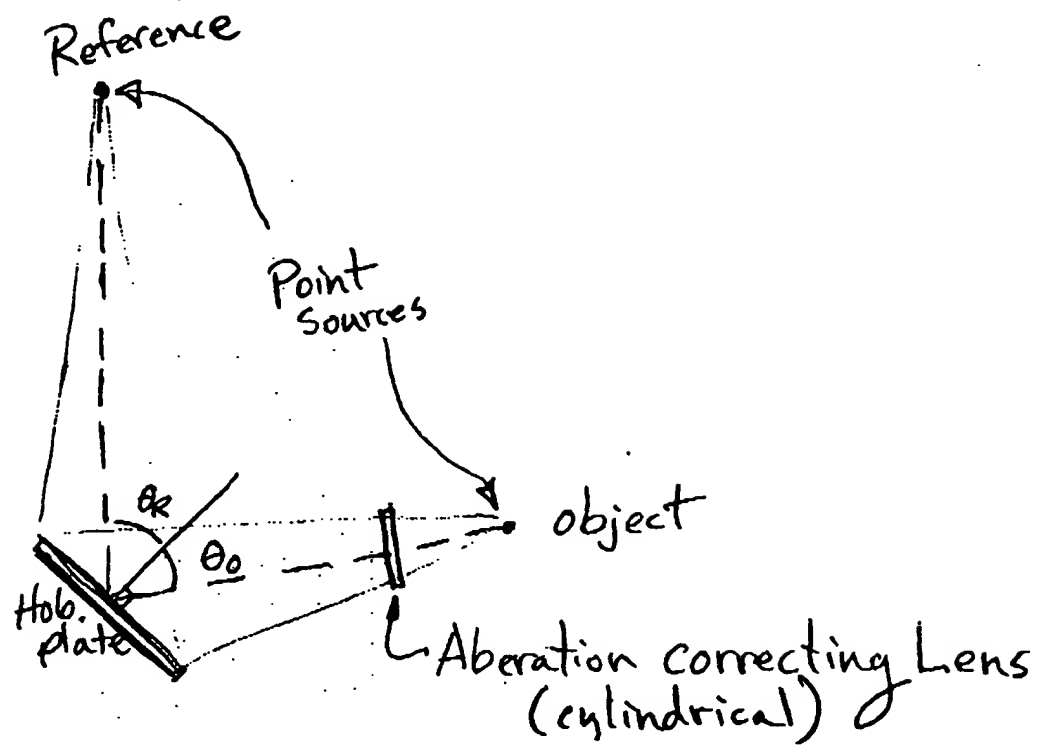
A ~

Convert the design parameters  $\Theta_{i1}, \Theta_{d1}, \Theta_{i2}, \Theta_{d2}$ , (and  $f_2$ ) expressed at the reconstruction wavelength  $\lambda_R$  into construction parameters expressed at the construction wavelength  $\lambda_C$ , namely:  $\Theta_{o1}, \Theta_{R1}$  for HOE H1; and  $\Theta_{o2}, \Theta_{R2}$  for HOE H2

B ~

In the case of variable gated frequency DOES, use computer-ray tracing to determine the distances of the object and reference (beam) sources relative to the holographic recording medium (as well as the distances of any aberration-correcting lenses therefrom) employed during the holographic recording process

FIG 4A



$\theta_o$  = OBJECT BEAM ANGLE OF INCIDENCE

$\theta_r$  = REFERENCE BEAM ANGLE OF INCIDENCE

FIG. 4B

formulate within a digital computer system, a mathematical description of the object and reference beam wavefronts used to construct DOE D1 and DOE D2, during optical formation thereof when using the Holographic Recording Method shown in Fig. 4B

use the digital computer system to formulate a mathematical description of the interference pattern that is generated by mathematically adding the mathematical model of the object beam wavefront to the reference beam wavefront, to provide a spatial function of the computer generated/represented interference pattern

use the digital computer system to sample the spatial function of the computer generated/represented interference pattern along the x and y directions thereof to produce a large set of sampled values of varying amplitude transmittance associated with the computer generated interference pattern

(A)

FIG. 4C1

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28/59

(A)  
↓

transfer the sampled light transmittance (reflection) values from the computer system to the drivers of a graphical plotting tool

use the set of sampled transmittance values to plot the two-dimensional sampled interference pattern on paper or other high resolution recording medium

photographically reduce the two-dimensional density (amplitude transmittance) plot on a light transmissive (or reflective) recording medium, to produce a master CGH for use in making CGH copies

use suitable copying apparatus to copy the CGH master onto a higher diffraction efficiency medium (DCG, photoresist, or suitable surface relief material) to form improved CGH copy

FIG. 4C2

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29/59

$$\{\theta_{i1}, \theta_{i2}, \theta_{d1}, \theta_{d2}, d_1, d_2, p\}$$

$$\{\theta_{01}, \theta_{R1}, \lambda_R\} \{\theta_{02}, \theta_{R2}, \lambda_R\}$$

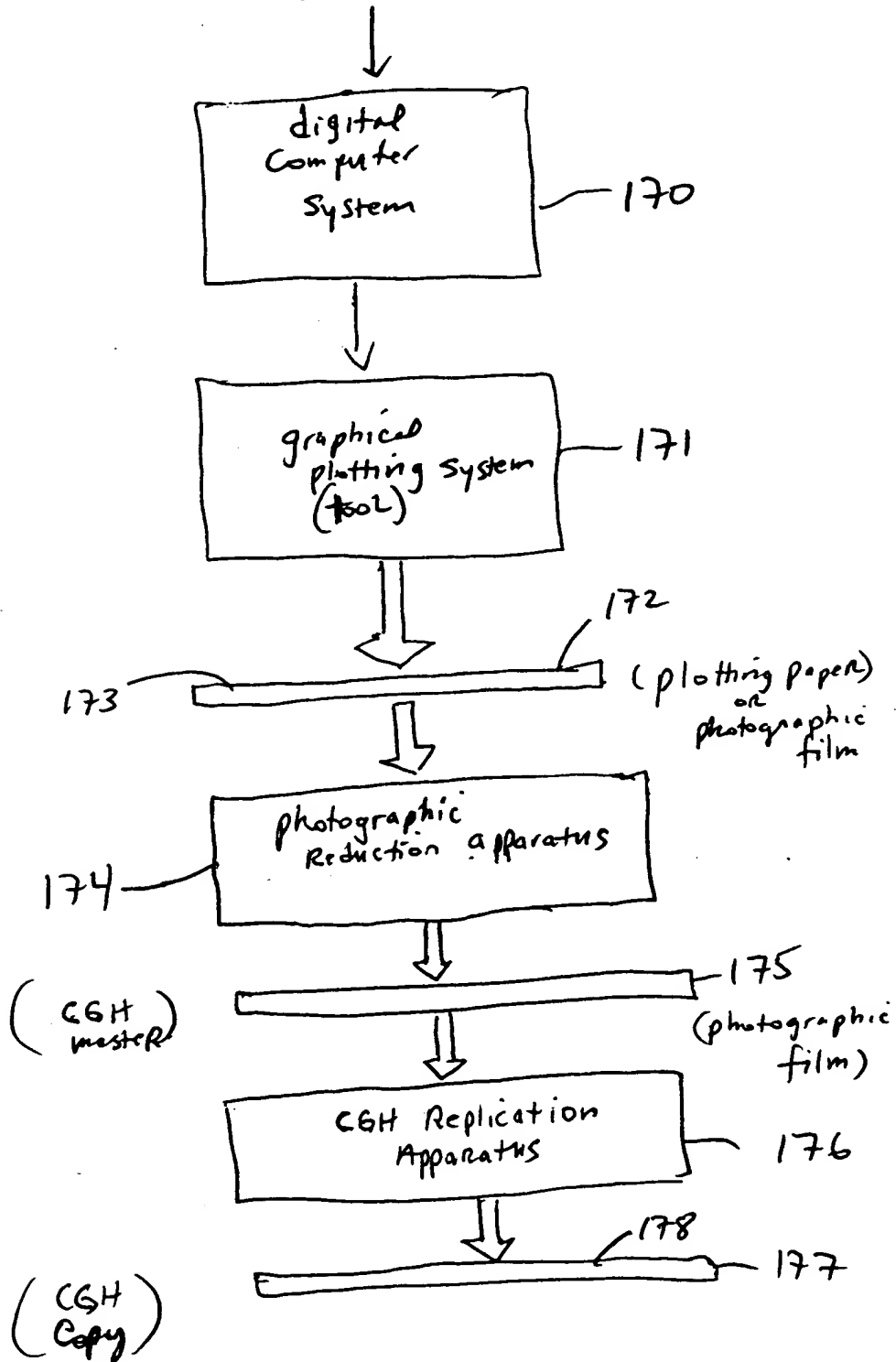


FIG 4D

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# Beam Dispersion Analysis

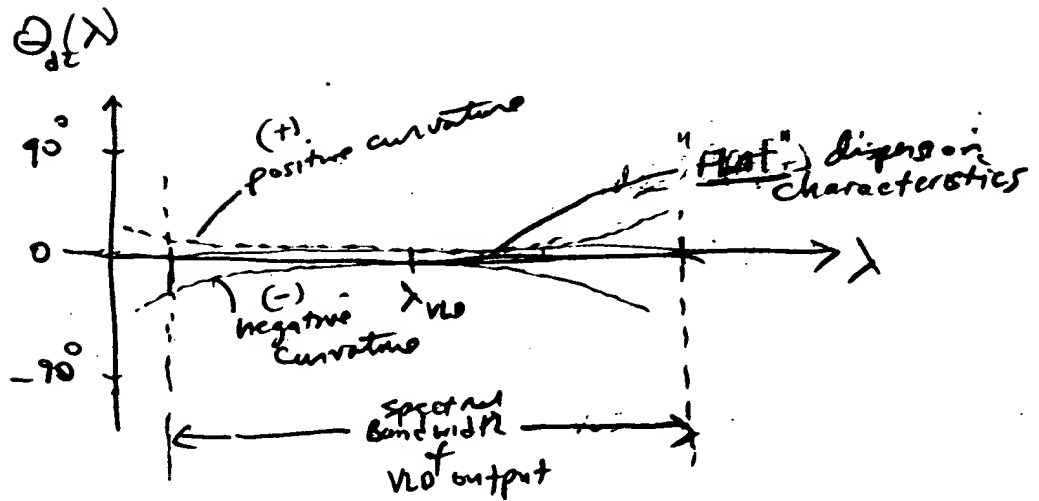
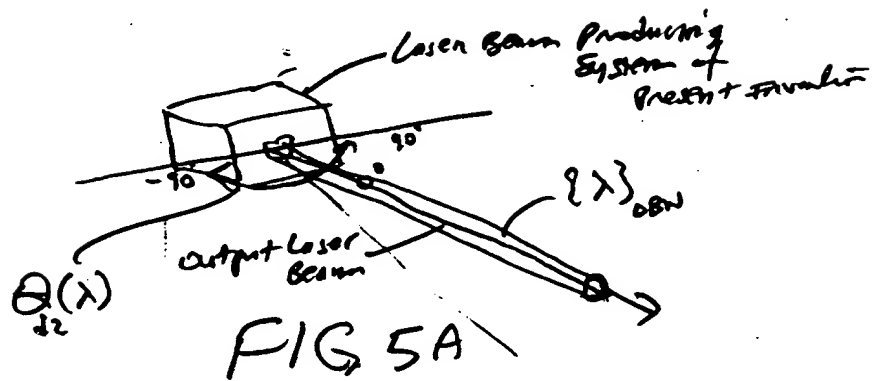


FIG 5B

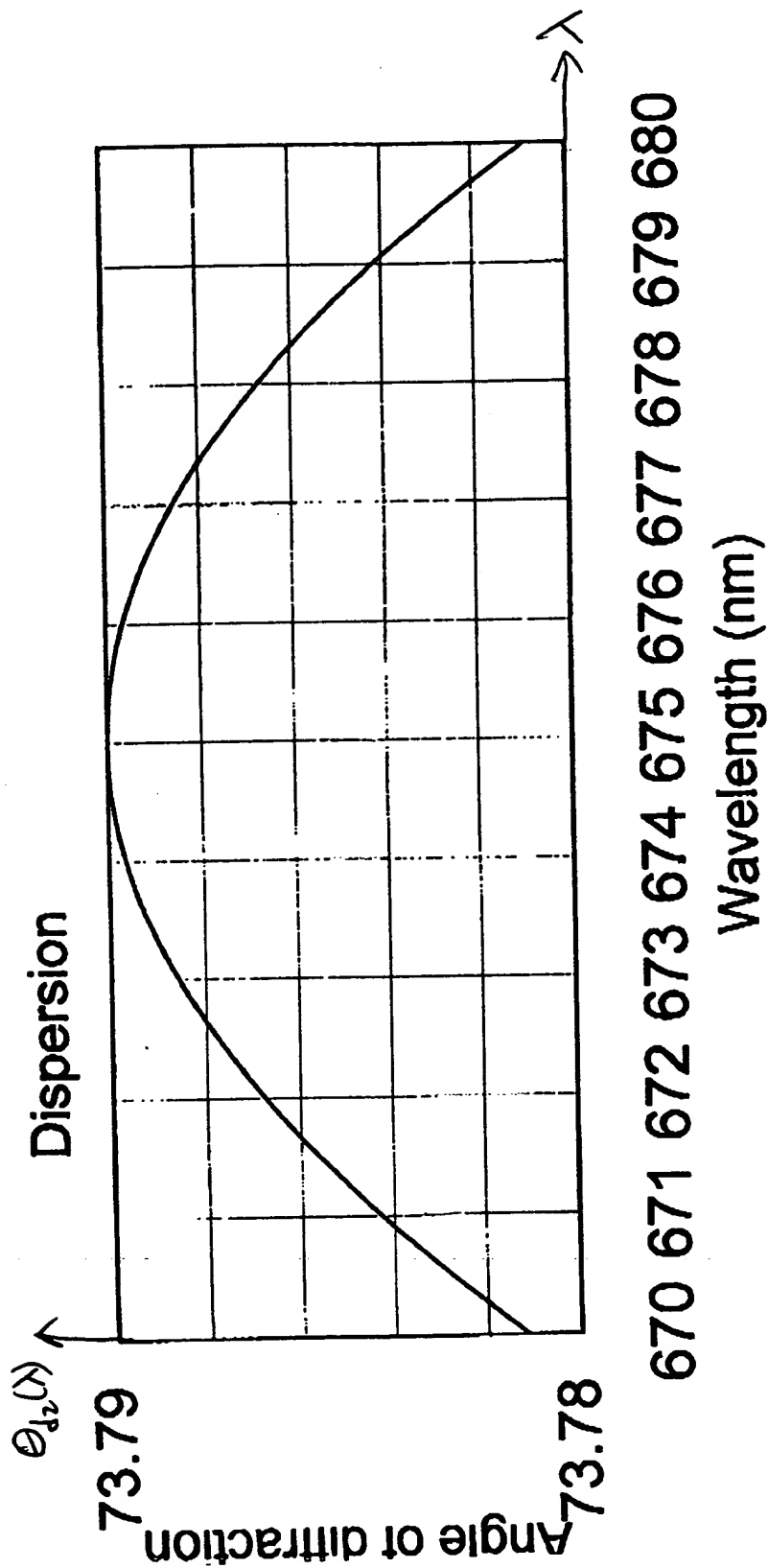


FIG 5B1

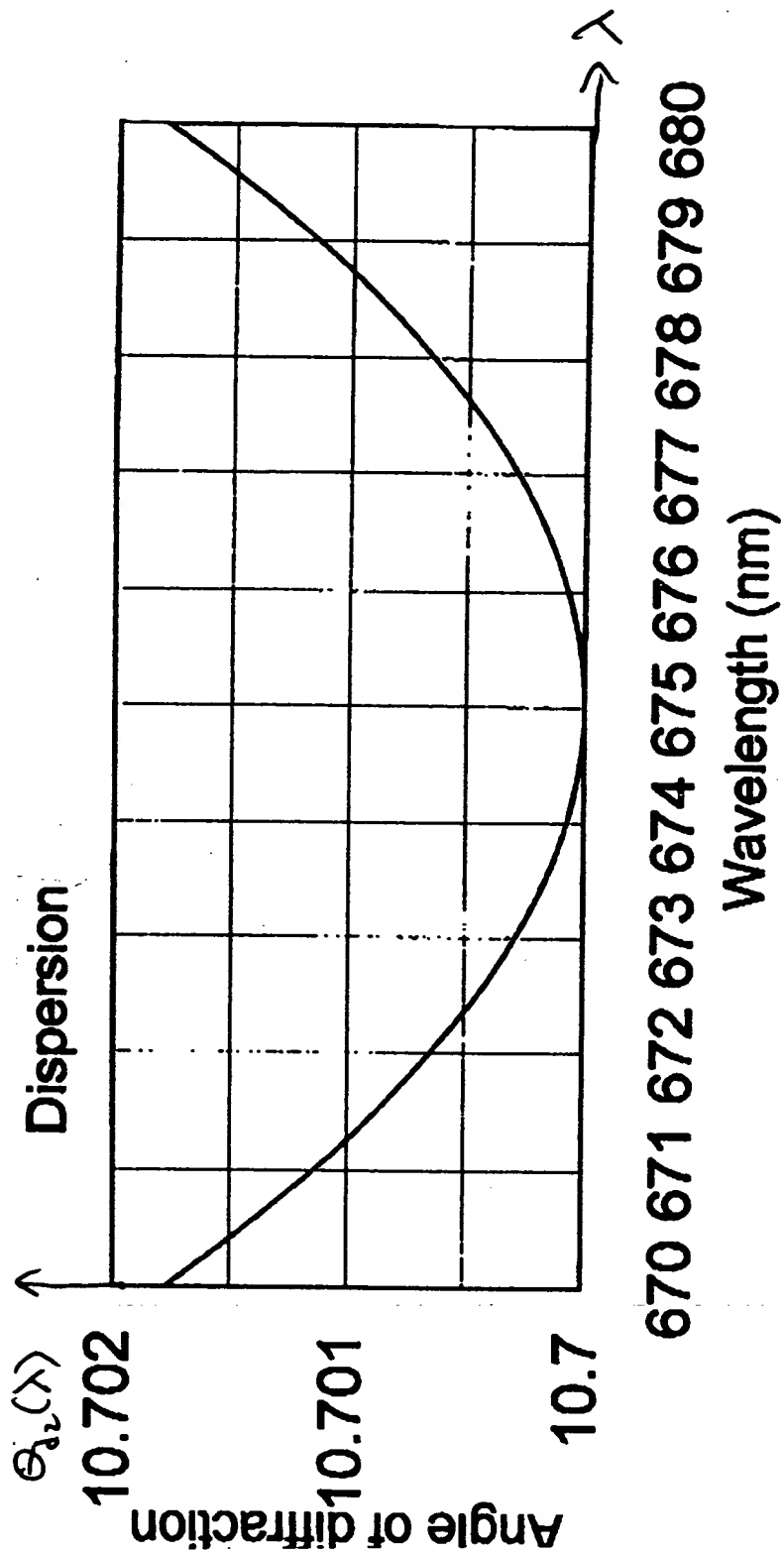


FIG. 5B2

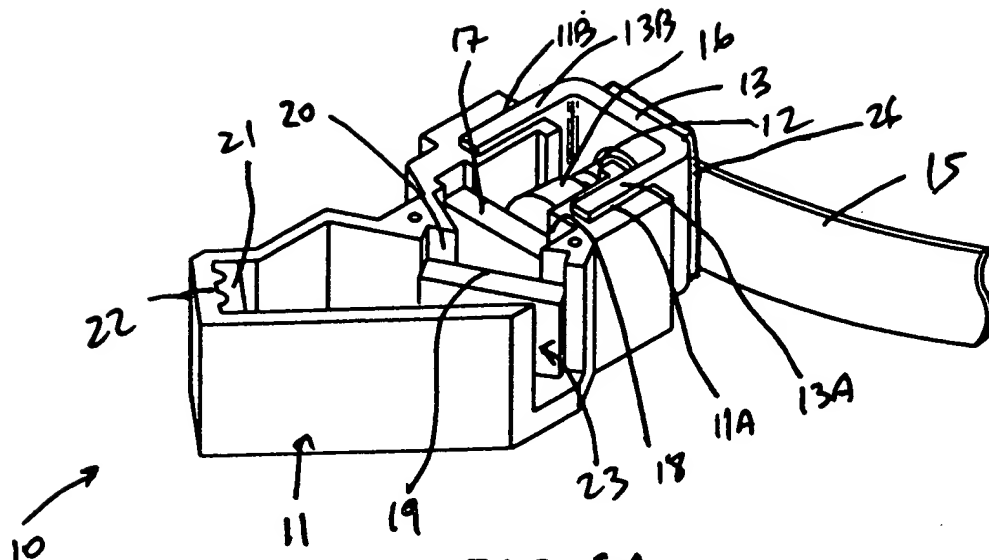


FIG. 6A

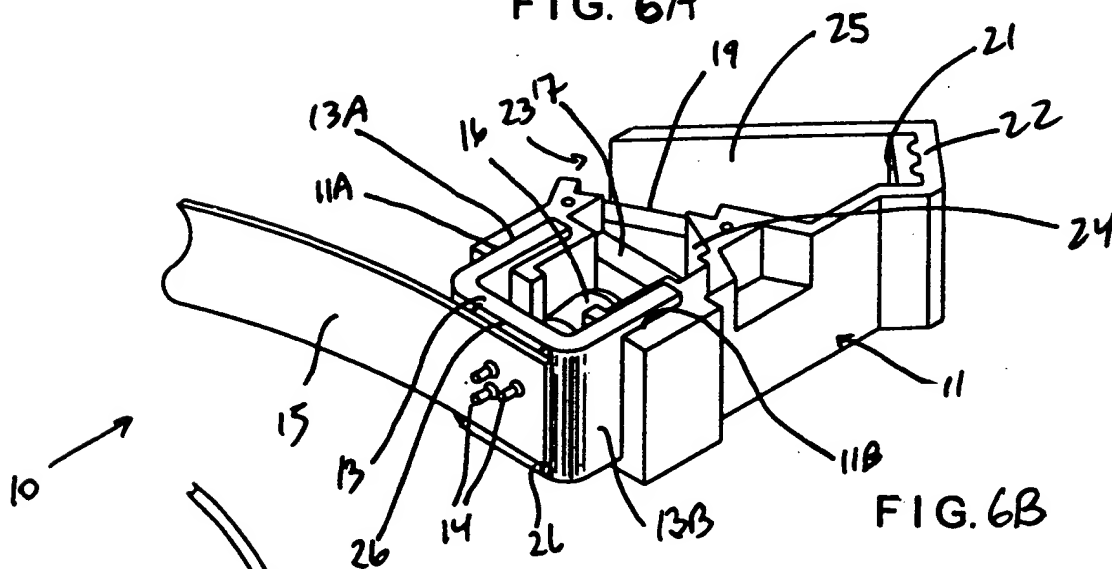


FIG. 6B

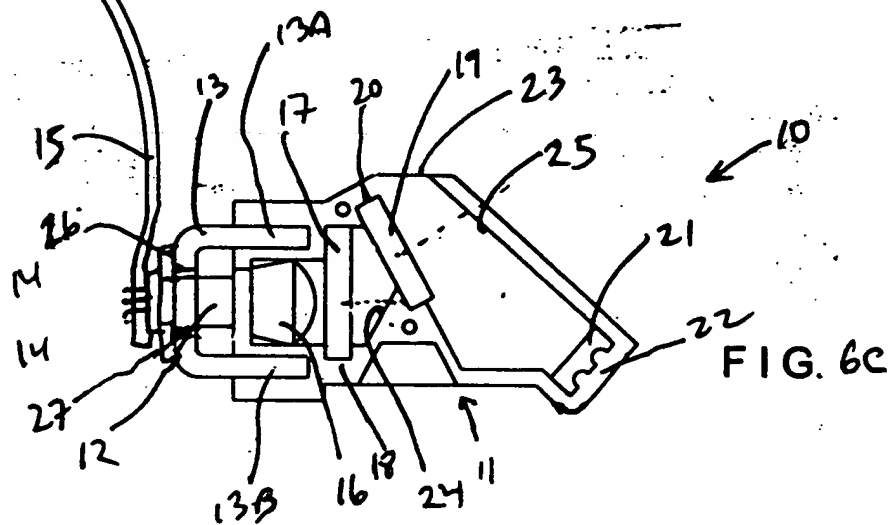


FIG. 6C

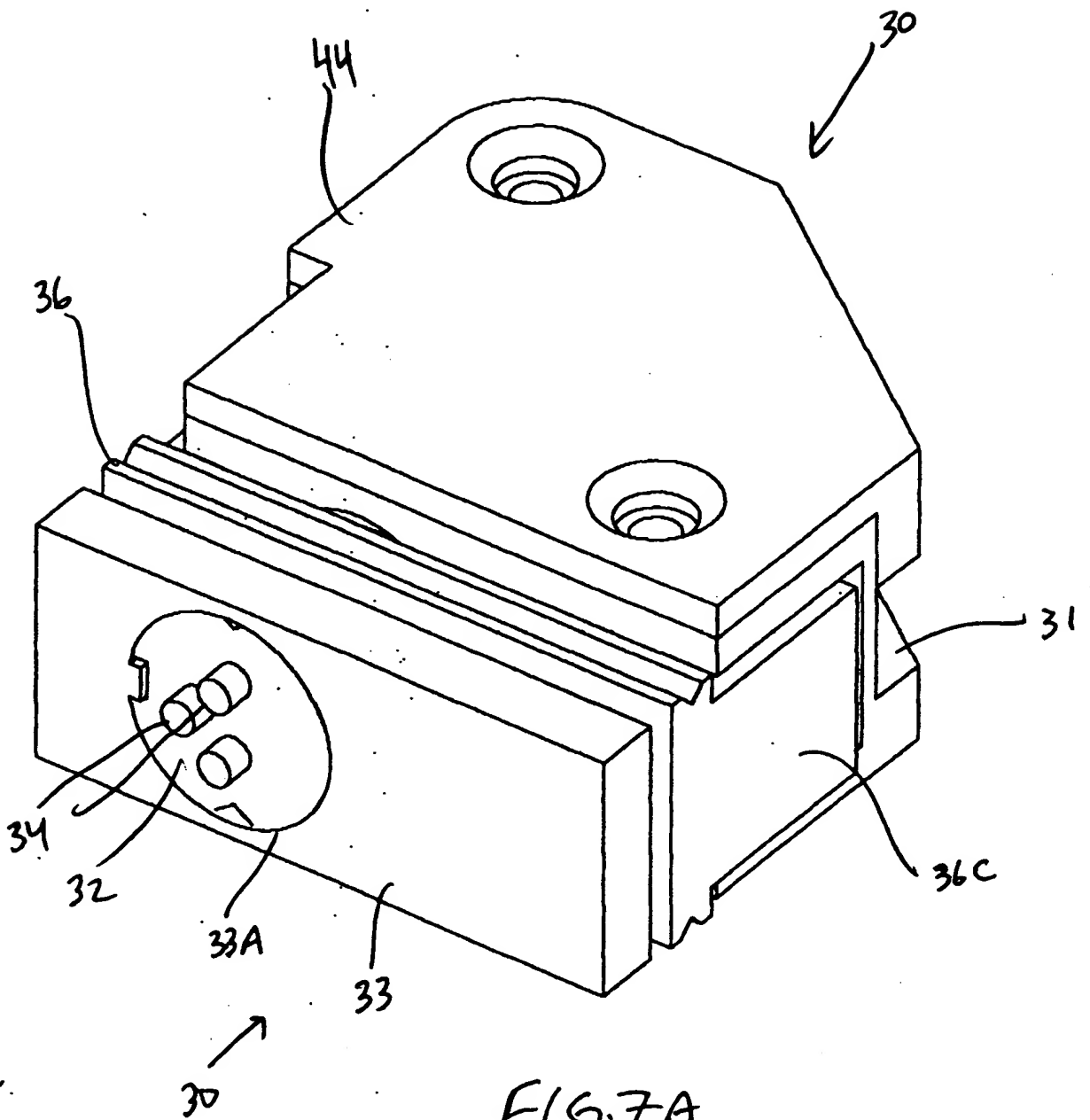
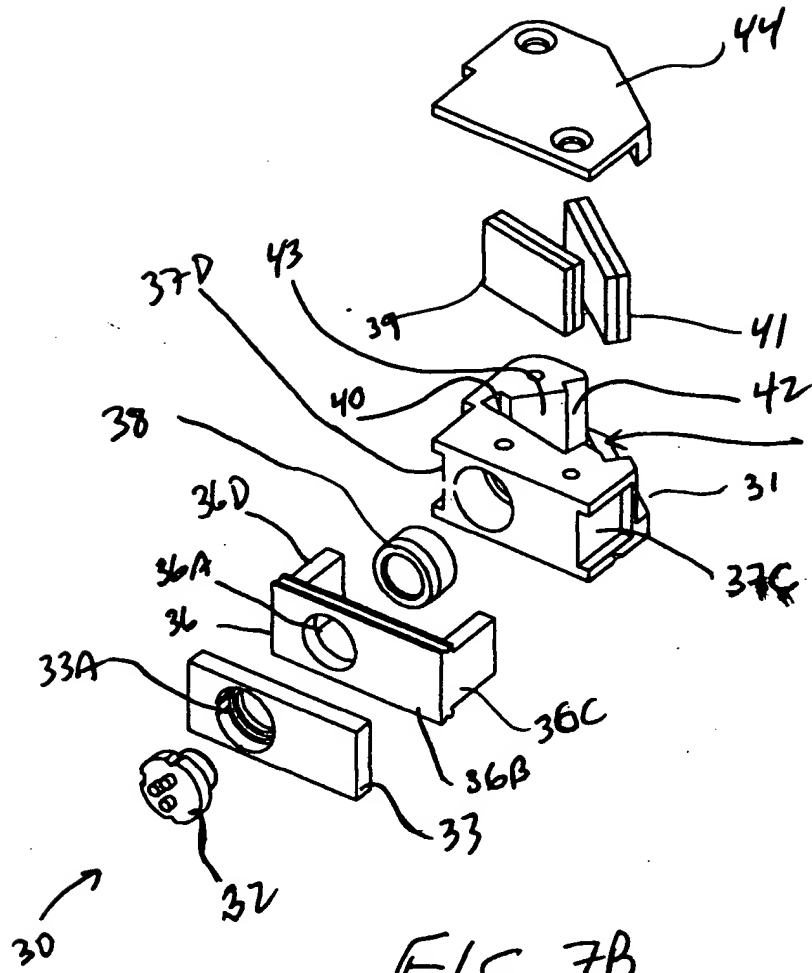


FIG. 7A

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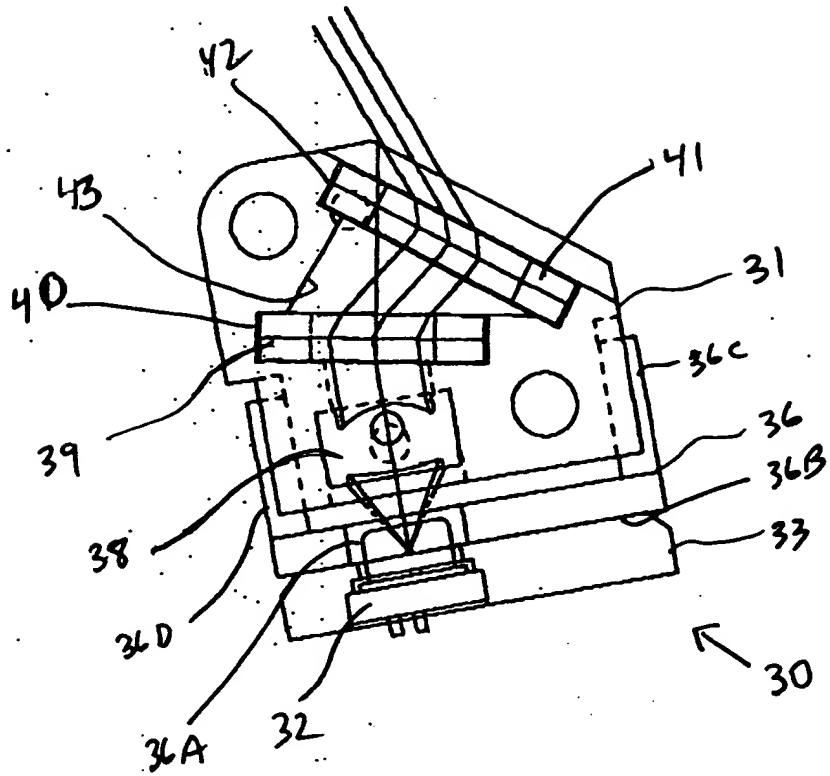
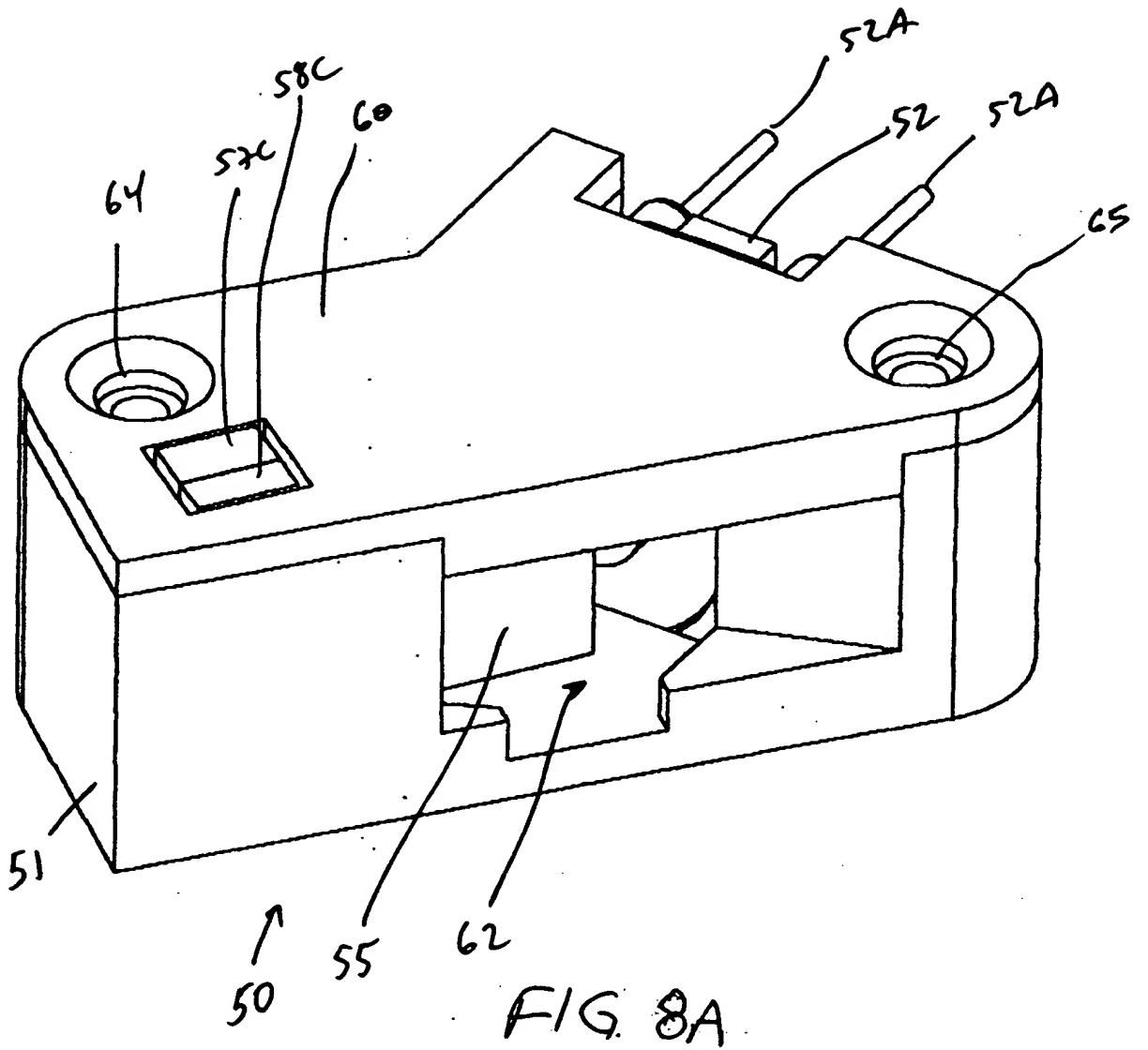


FIG. 7C



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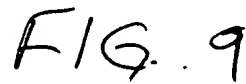
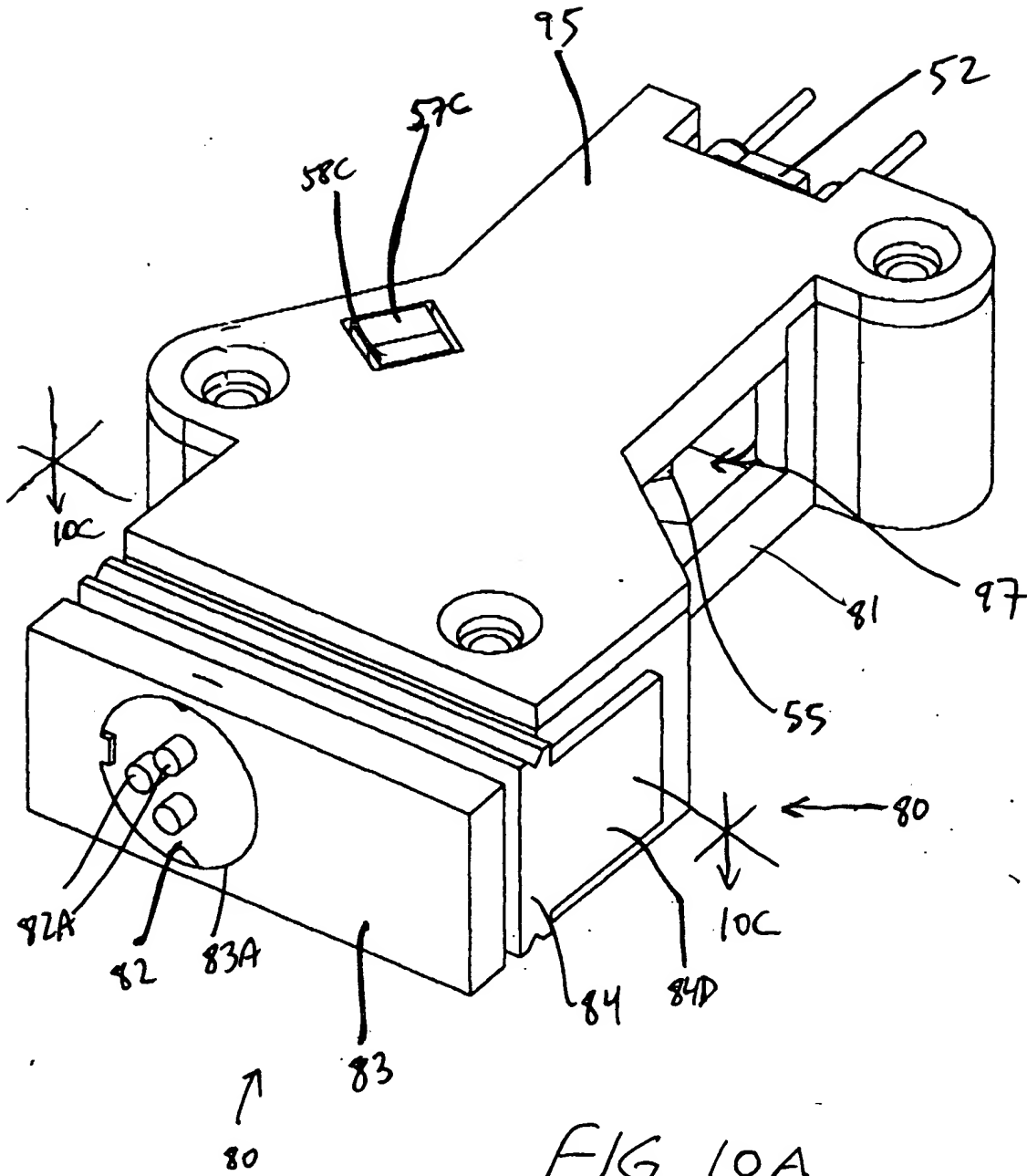
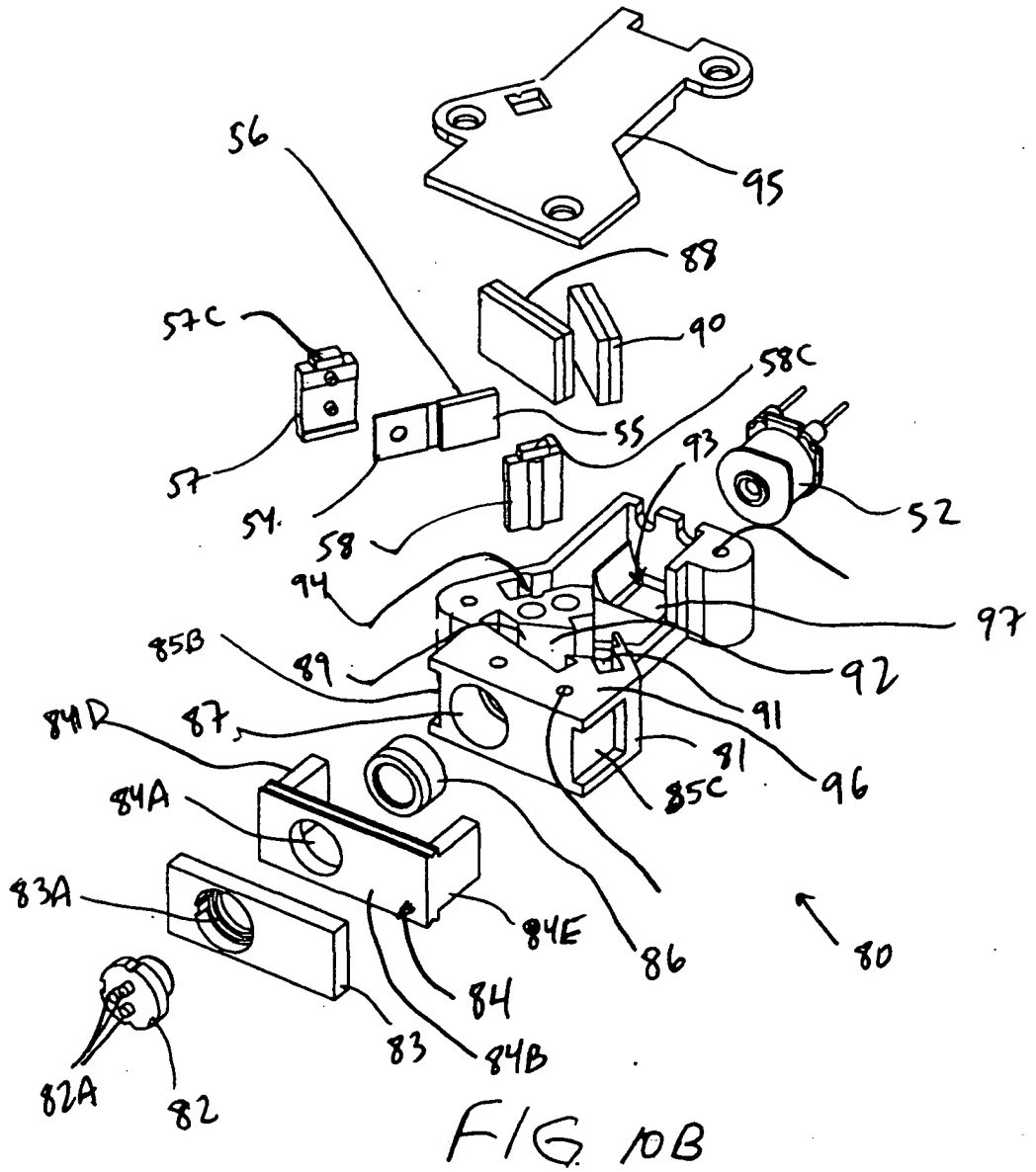


FIG. 9

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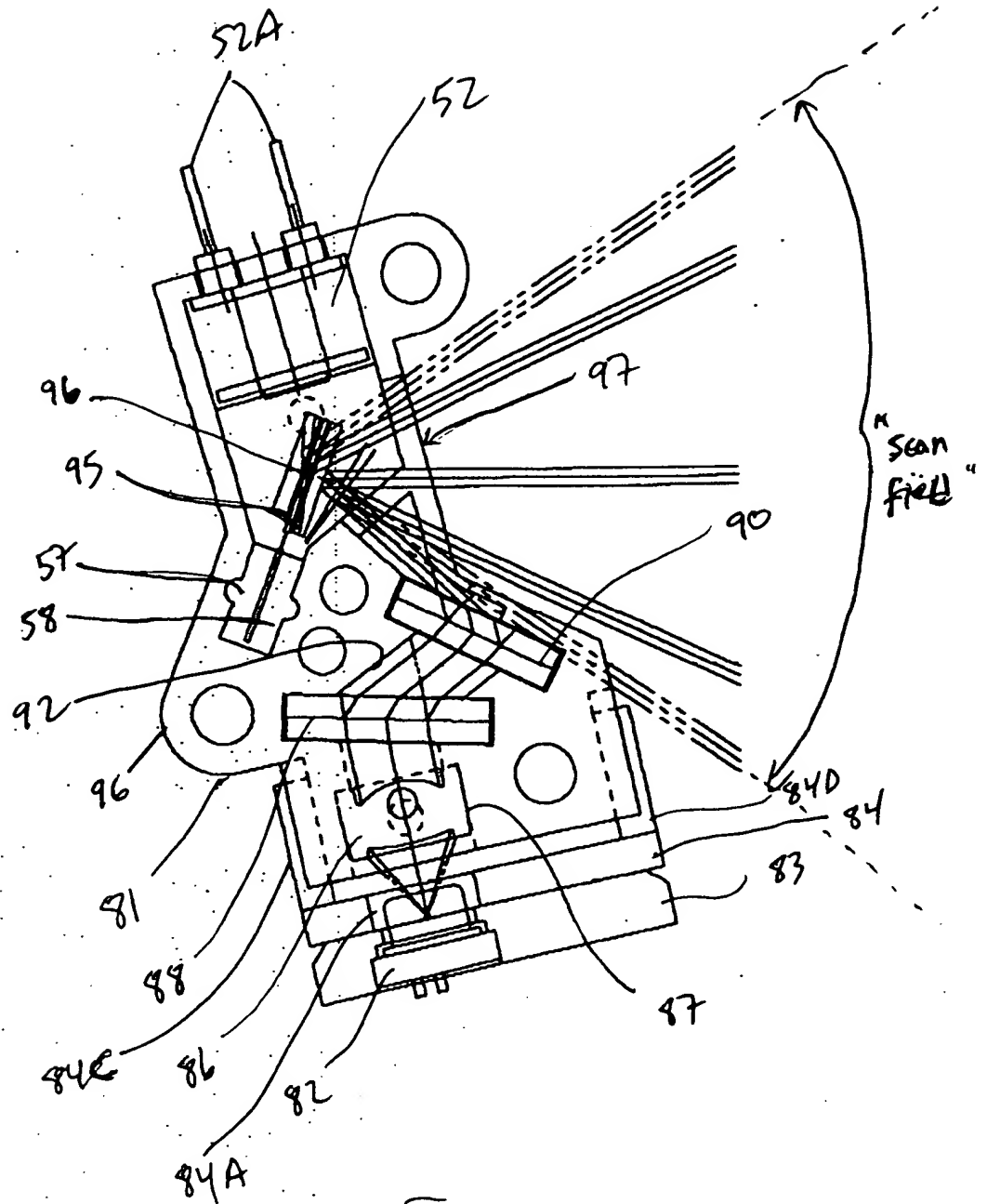


FIG 10C

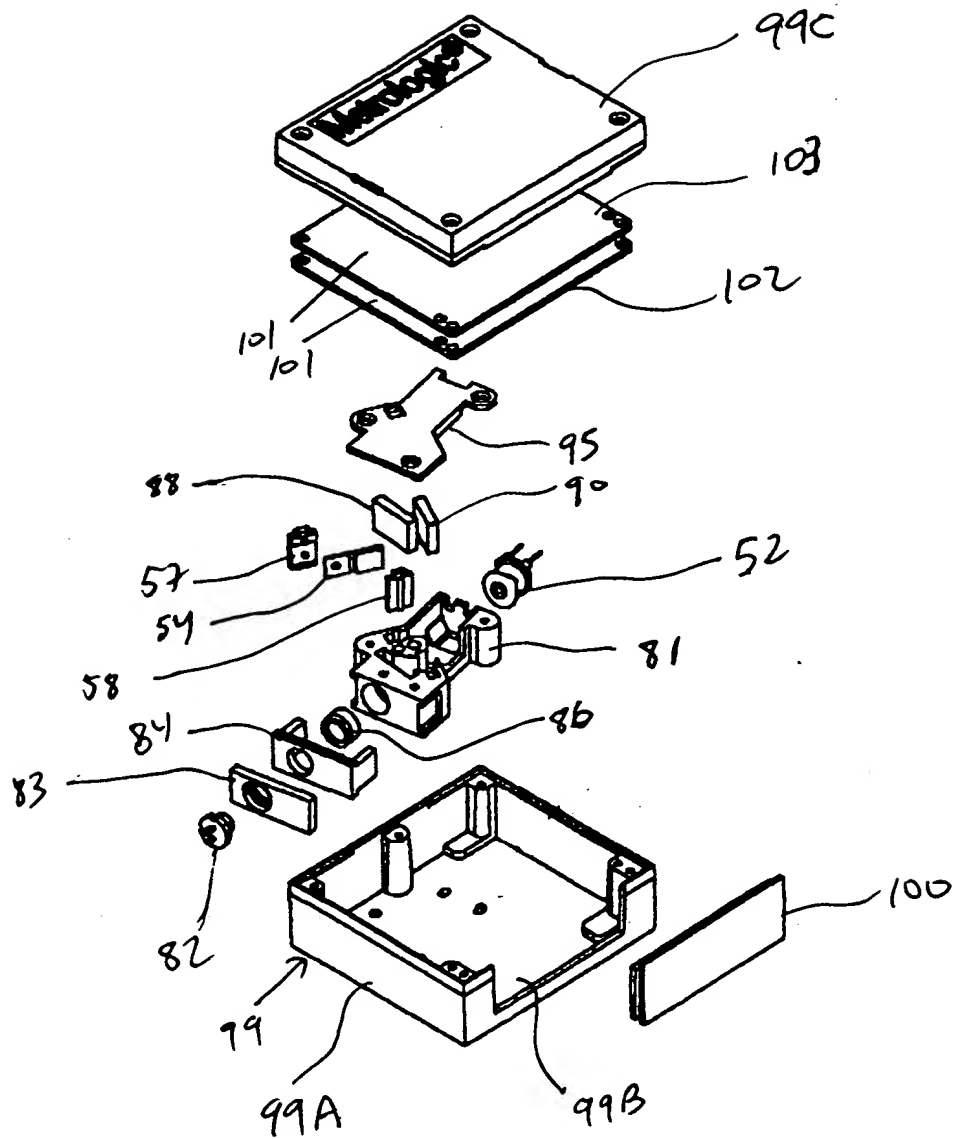


FIG. 10D

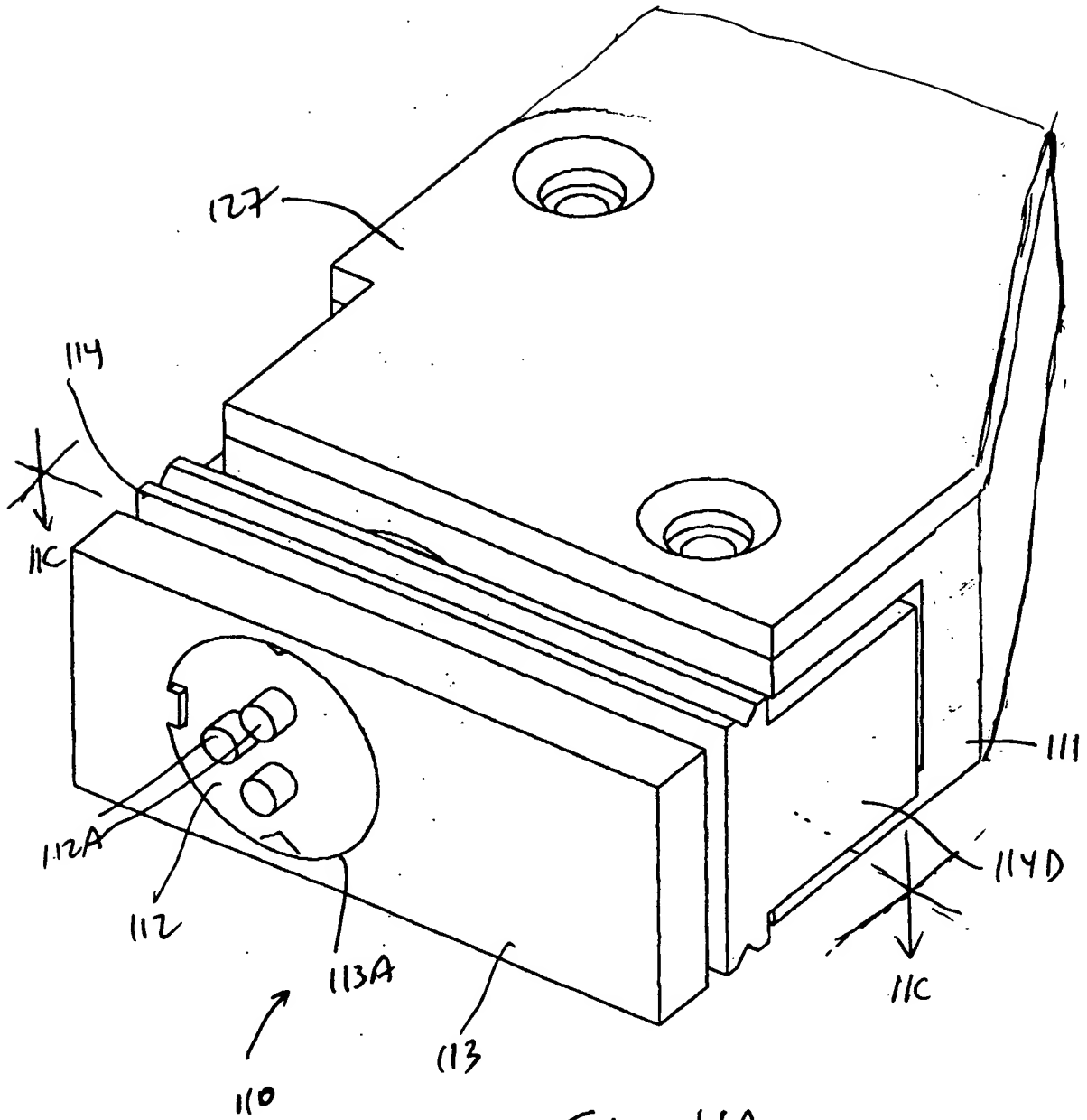


FIG. 11A

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45/59

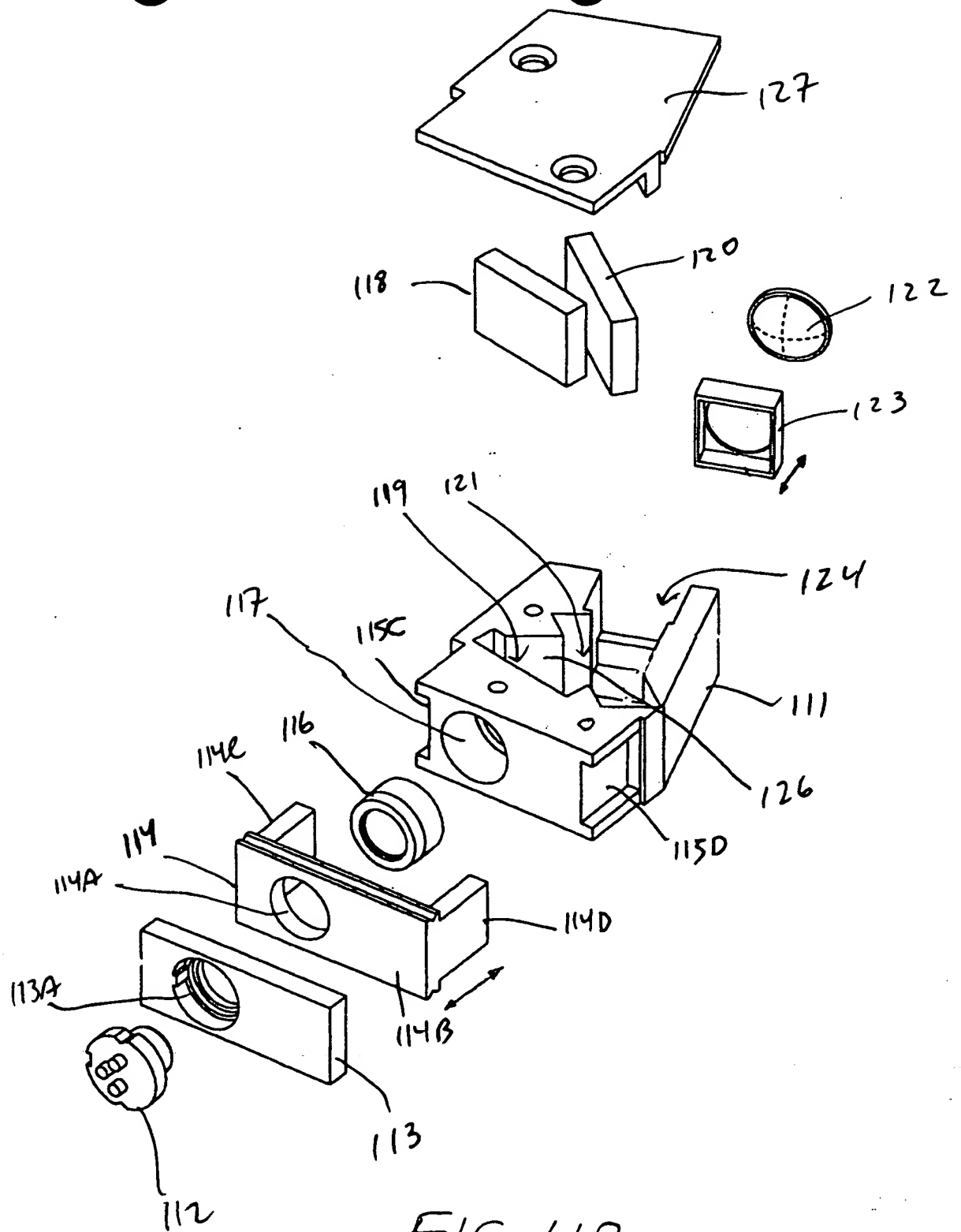


FIG. 11B

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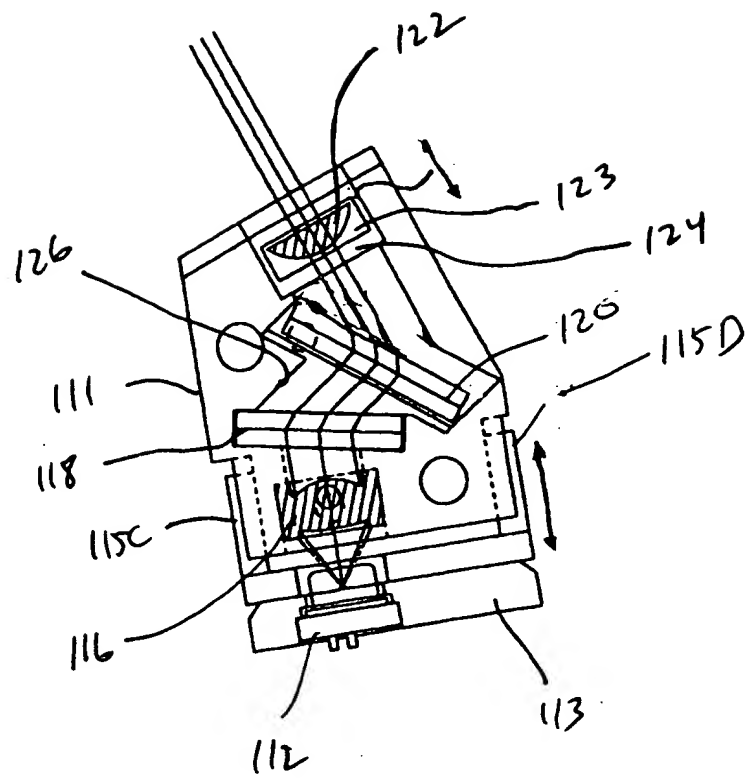
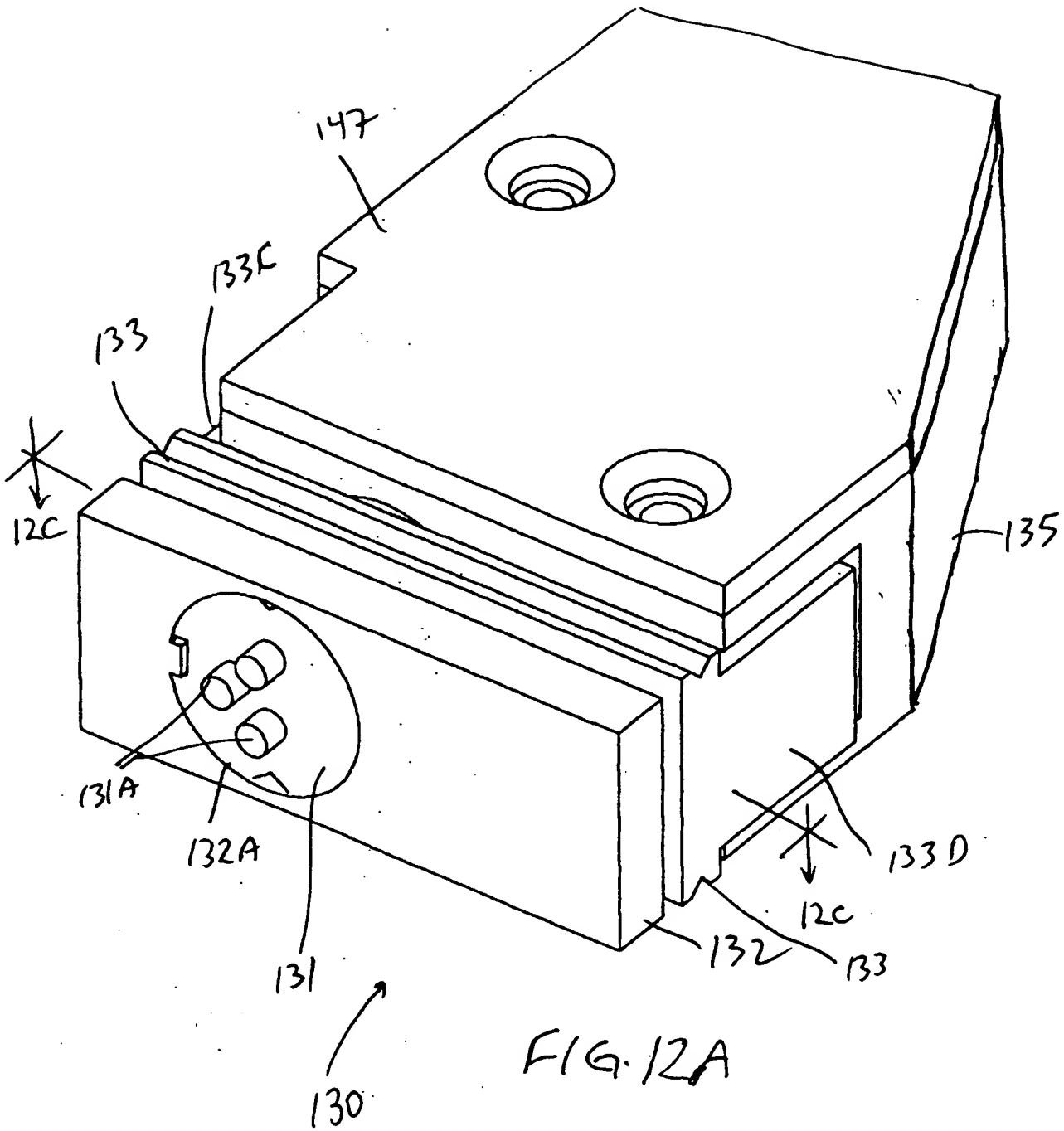


FIG. 11C

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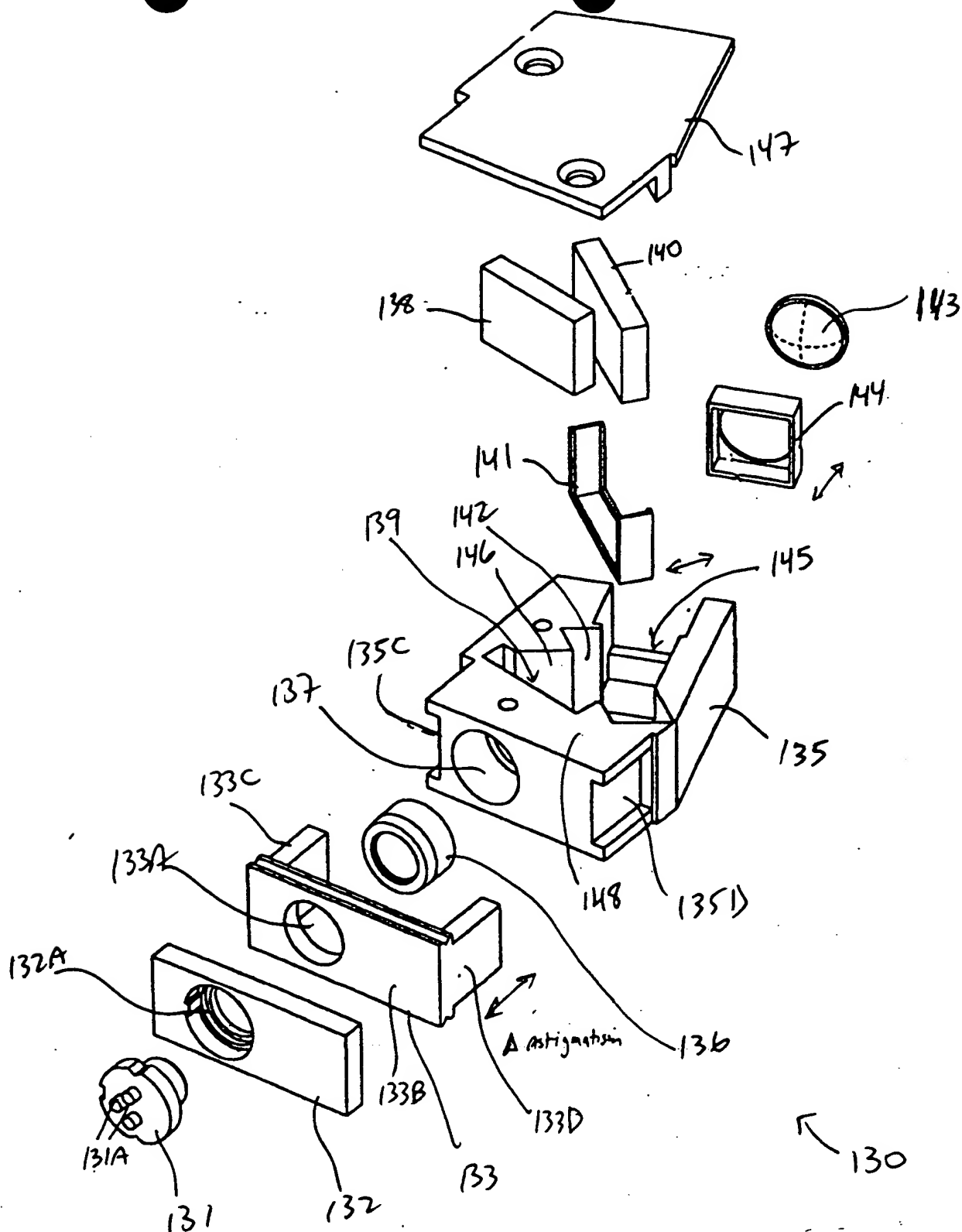


FIG. 12B

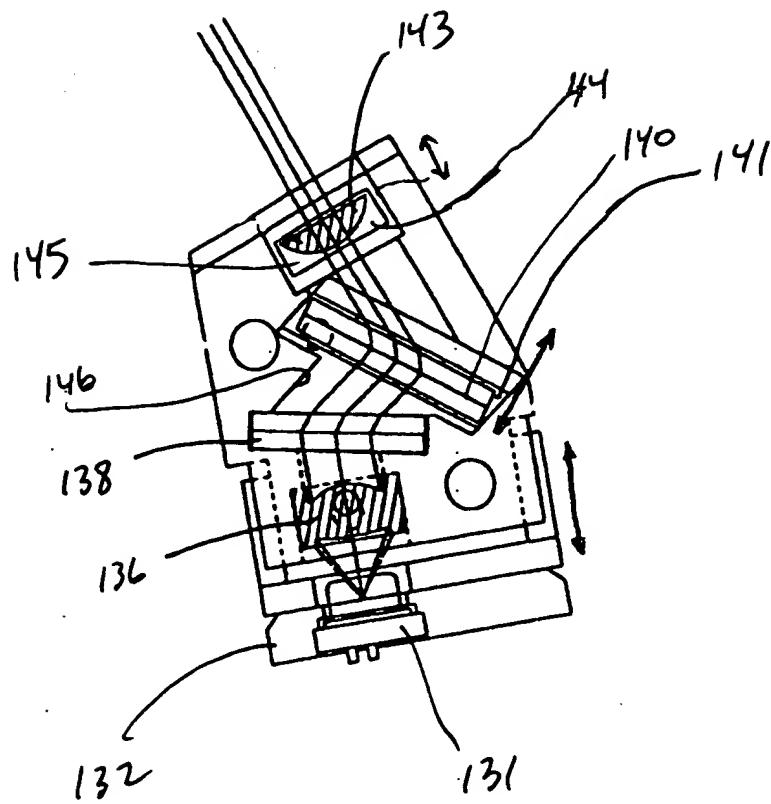


FIG. 12C

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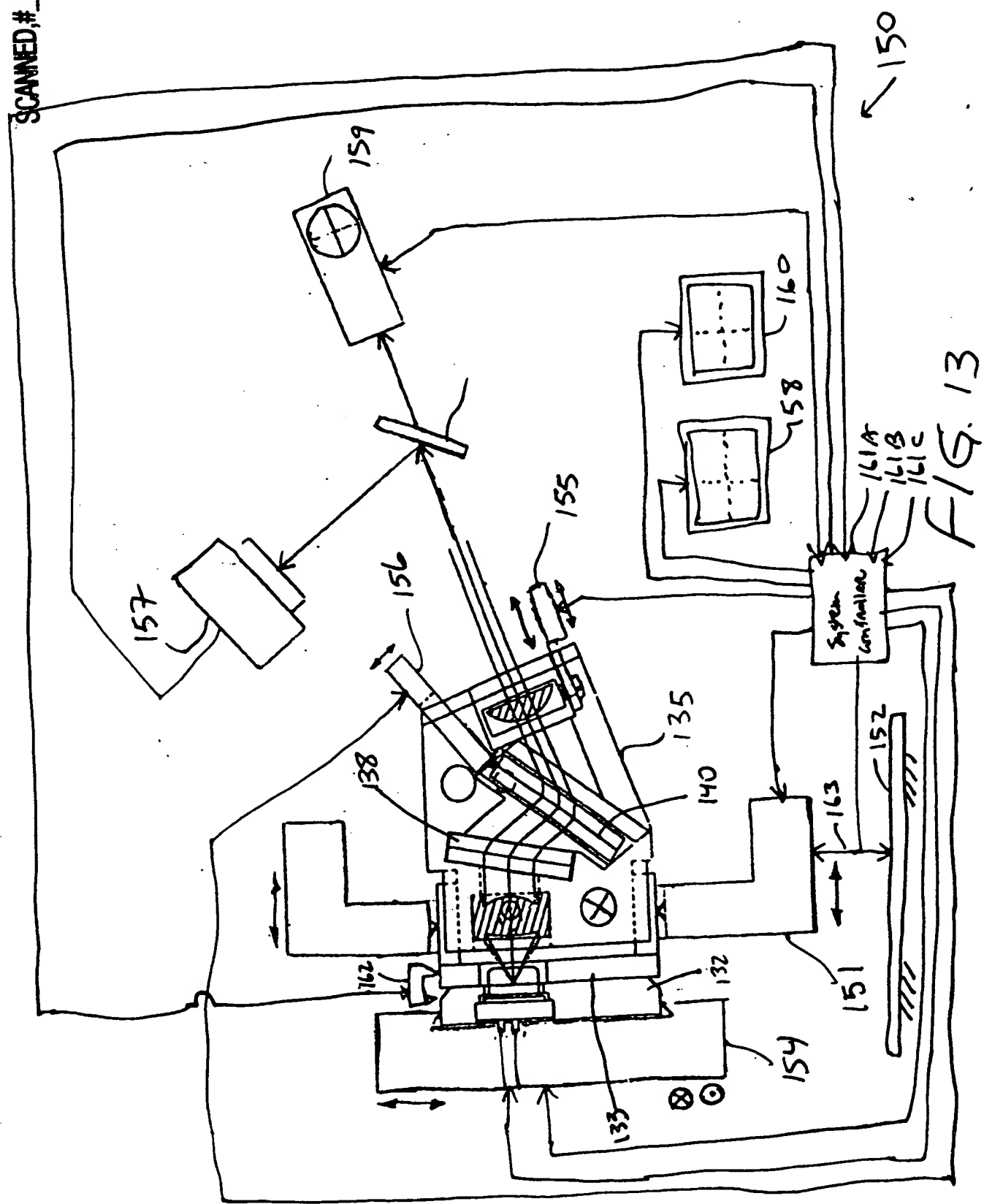


FIG. 13

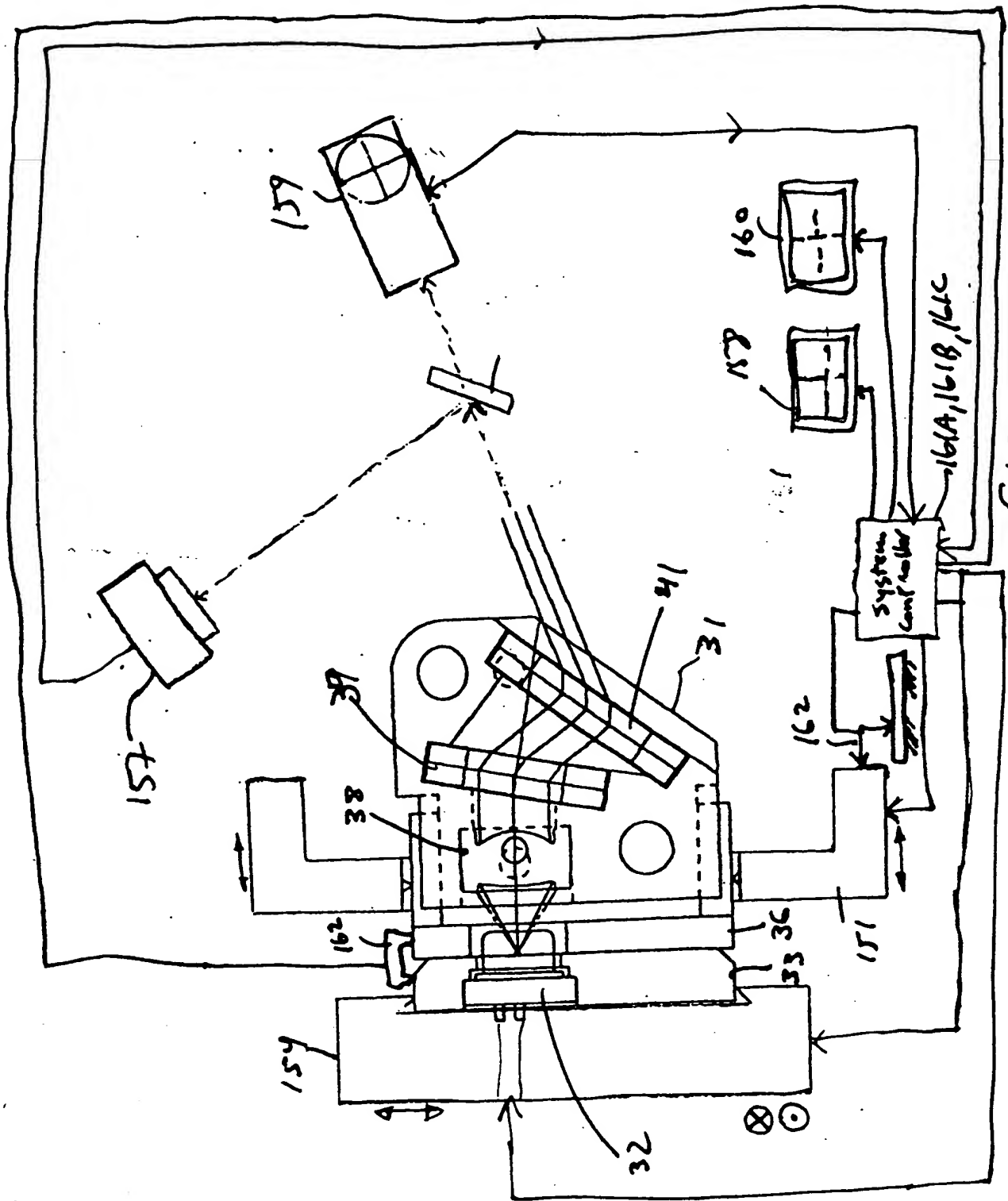


FIG. 14  
(Case A)

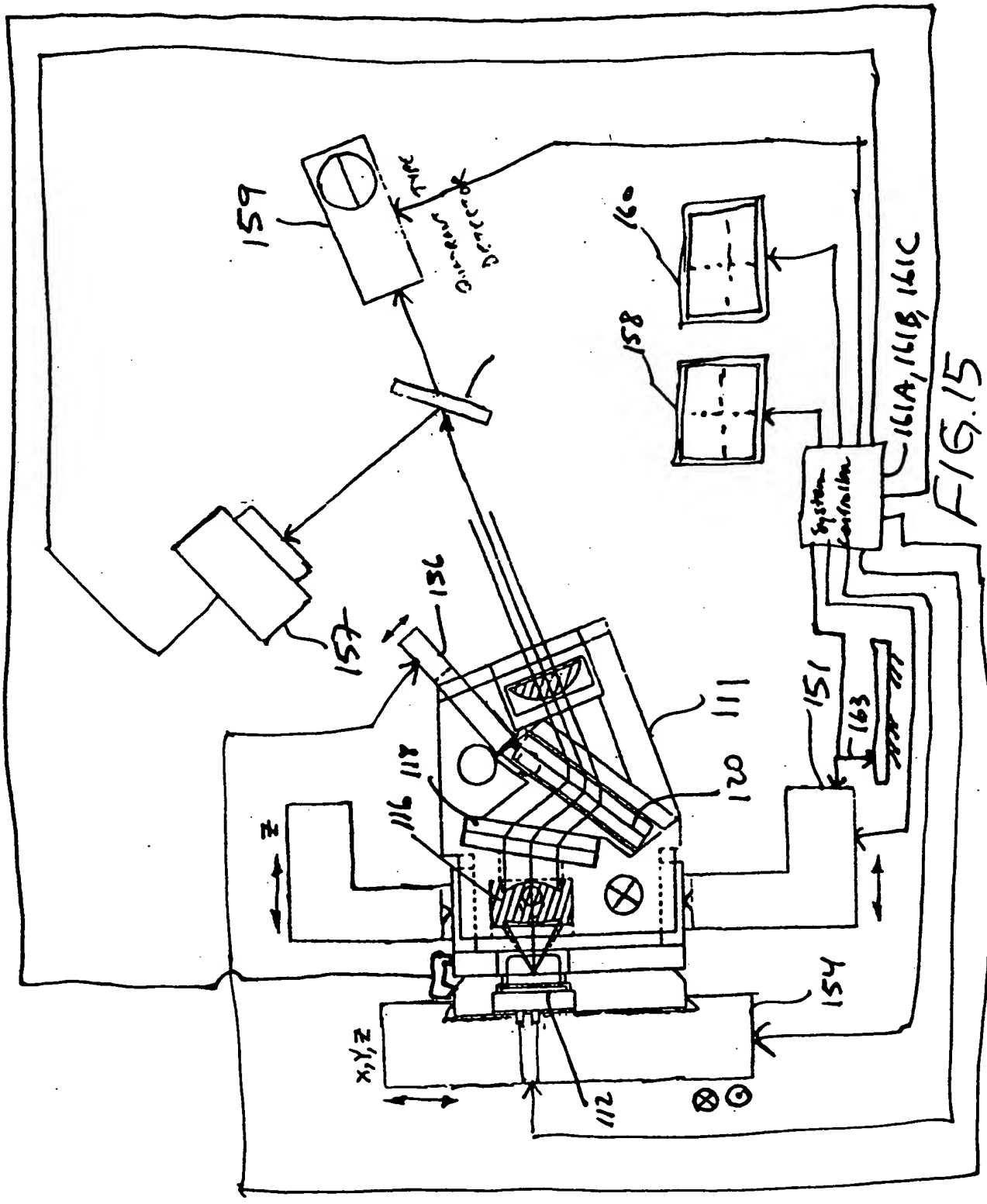
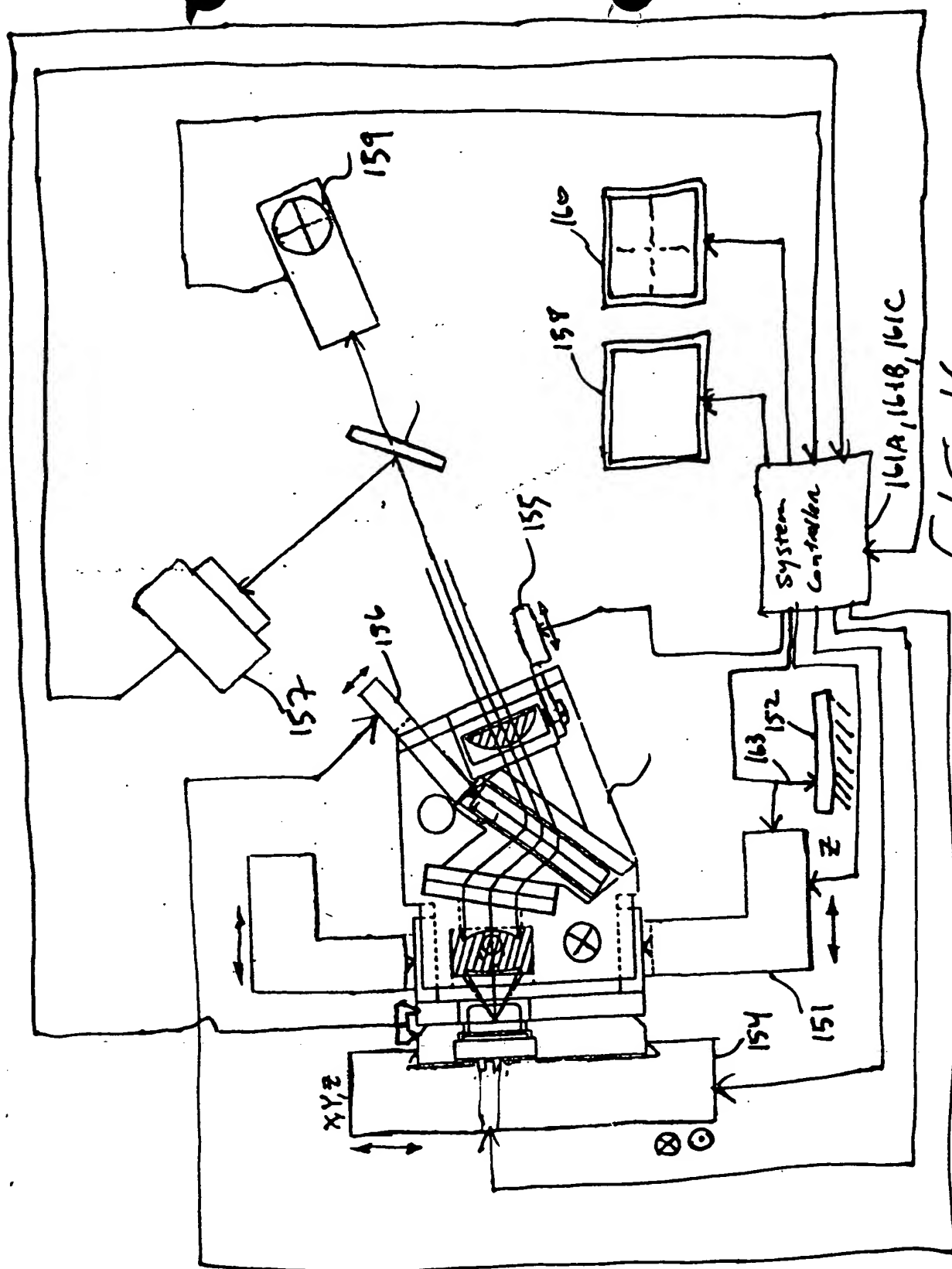


FIG. 15  
(Case B)



(Case C)

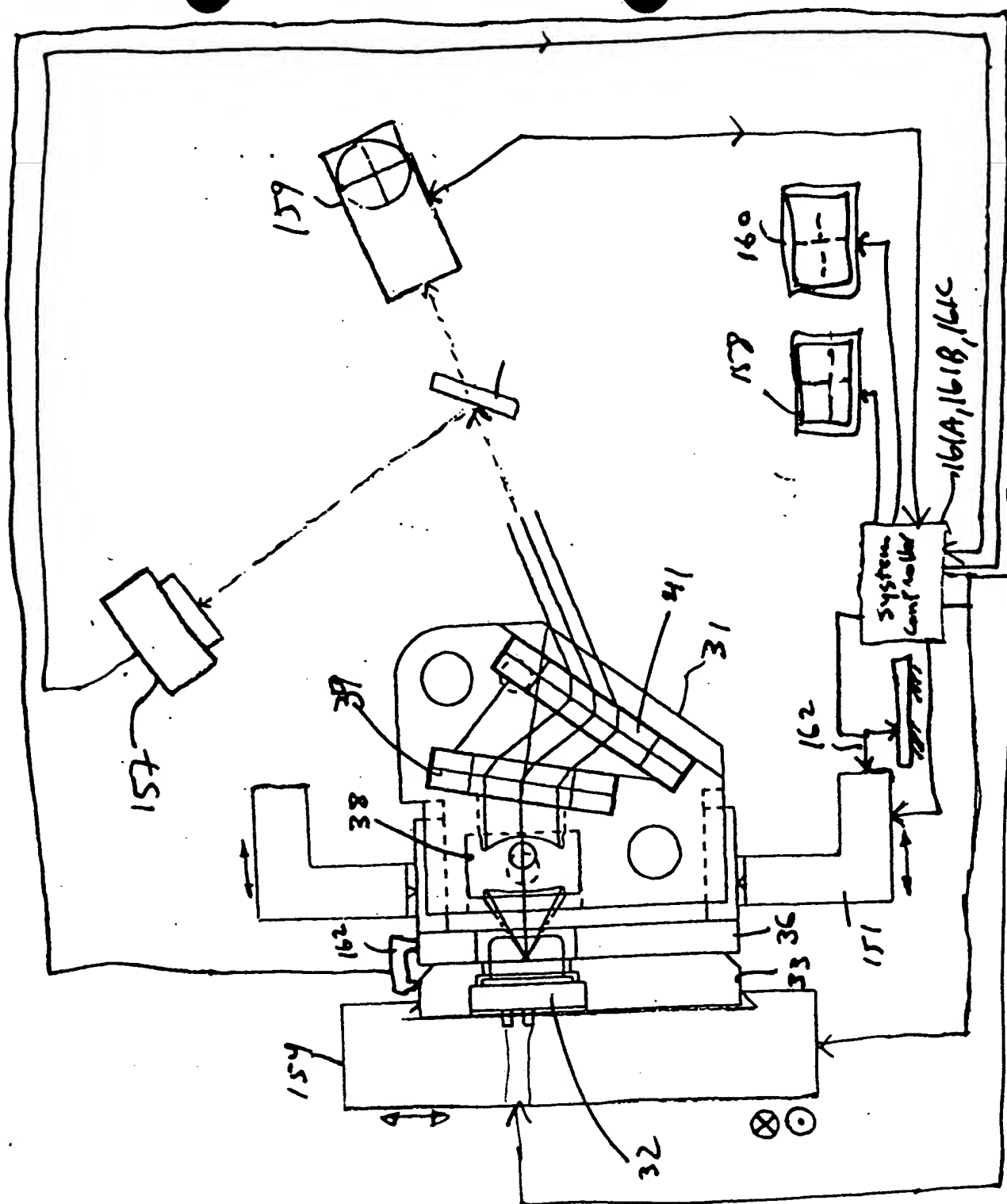
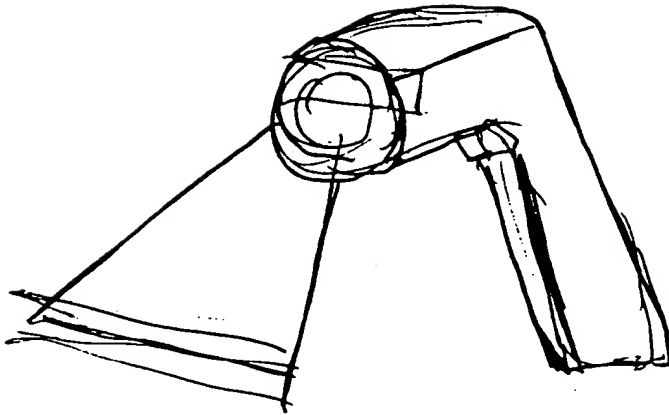


FIG. 17:

(over)

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Z-D

FIG 18

56/59

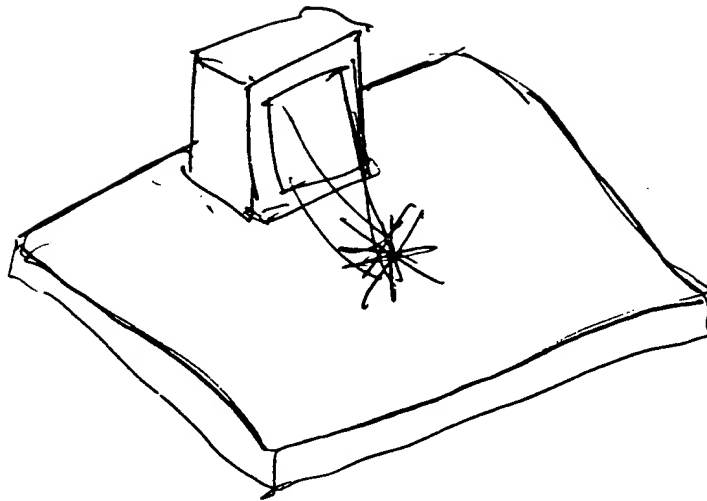


FIG. 19

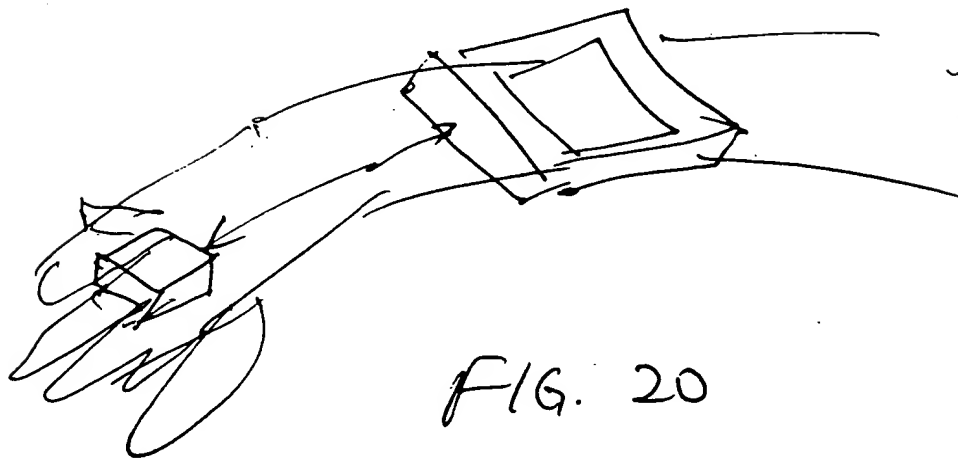


FIG. 20

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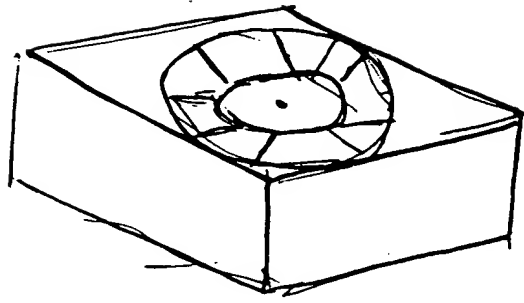


FIG. 21

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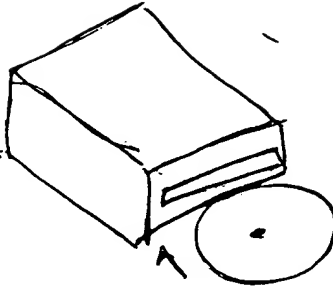


FIG. 21

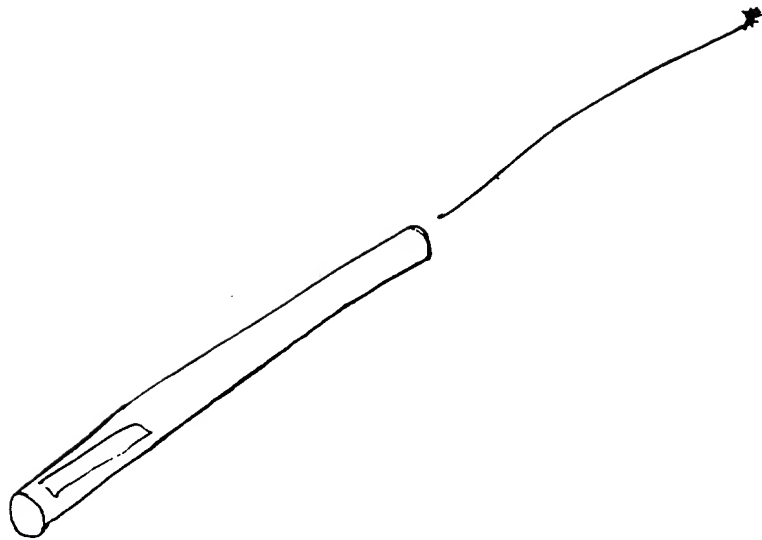


FIG. 22

59/59

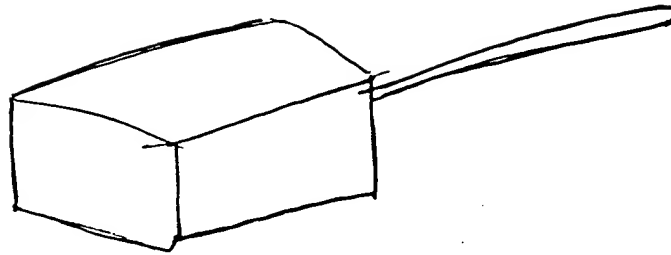


FIG. 24

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